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Traction Farming and Traction Engineering

Gasoline — Alcohol — Kerosene

A Practical Hand-Book for the Owners and Operators of Gas and Oil Engines on the Farm

COMPRISING

A Full Description of the Leading Makes of Farm Tractors with Directions for their Care and Operation

ALSO

Engines for Water Supply and Electric Lighting on the Farm. A Special Section Devoted to Threshing Machines

AND

THE SCIENCE OF THRESHING

By JAMES H. STEPHENSON, M. E.
Author of "Farm Engines and How to Run Them," "The Young Engineer's Guide," Etc., Etc.

Fully Illustrated

CHICAGO

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PREFACE

THE marvelous development within recent years of gasoline and oil traction engineering and its adaption to agricultural needs, very naturally creates a demand on the part of those directly connected with the operation of these engines, for a more extended and practical knowledge of the details of construction and operation of this type of motors. The supply of reliable and practical books dealing with this phase of the farmer's work has not kept pace with the demand for information bearing upon the subject, and no one knows this better than the men who are called upon to care for and operate these machines. Many changes and improvements have been made in the details of construction and methods of manipulation of gas and oil tractors designed for farm work, and it is with a view of enabling the men who are responsible for the successful operation of these engines to become proficient in their calling and to obtain a practical knowledge of every detail connected therewith that this volume is written. Much care has been exercised in its preparation, and an earnest effort made to place before the reader a reliable and practical guide and instructor for the gas engineer.

The larger portion of the book deals exclusively with gas and oil tractors, giving a complete exposition of the principles controlling the action of these engines, to-

gether with full details relative to the construction, care and operation of many of the more prominent types.

Part II deals with the problems of lighting and water supply for the farm home. Modern genius has made it possible for the farmer to equip his home with practically all the conveniences and comforts of city life, such as electric light for the house, barn and other out-buildings, also a water system whereby an abundant supply of water is made available for the use of the family and the stock. Both the electric light and water pumping systems are operated by gasoline or oil engines, all being fully described and illustrated.

Part III is devoted to the subject of threshing and the operation of threshing machines by means of the gasoline or oil tractor. Complete descriptions of the leading types of threshers are given, together with illustrations of the same, also harvesting machines, ploughs, and other farm machinery, all of which may be operated by means of the tractor.

TRACTION FARMING AND TRACTION ENGINEERING

PART I

CHAPTER I.

THE GASOLINE FARM TRACTOR.

THE gasoline motor, adapted as it is to the use of fuel in the form of gasoline, kerosene and alcohol, furnishes a source of power for both traction and stationary purposes that is at once economical, clean and safe, and is able to develop power from a fuel, the supply of which is practically inexhaustible. The use of the gasoline motor has become so general that we find it in use everywhere, and practically for all purposes where power is needed.

One of the most hopeful signs, and one which presages future prosperity, is the rapidly increasing use of gasoline traction engines on the farm. Mechanical power applied to the heavy work on the farm enables larger areas to be handled, and as a consequence the production is increased accordingly. Because the farmer is aided by mechanical power to make the earth yield more abundantly, the city dweller is able to obtain the necessaries of life at a less cost than would be the case if all labor was done by hand.

The farm tractor is rapidly becoming the horse that will do all the hard work. It plows and prepares the

ground for seeding, it harvests the corn and grain, shells, threshes, separates and cleans the crops for market. It shreds the cornstalks for silage and fodder and helps in building country roads.

The average weight of a gasoline or oil traction engine should be from five to ten tons. Such a machine as this should develop from fifteen to forty horse power and be relied on at all times to perform the hard work usually performed by the horse.

A good gasoline traction engine while hauling a gang of eight plows can easily turn over in a day from twenty to twenty-five acres. When smaller plows are required the disc may be used to good advantage as it rolls over stones or other obstructions that are sometimes encountered, and which might cause trouble for a mould board plow.

One of the successful practices on the farms of the west is to hitch a harvester and binder to the traction engine. Vast fields of grain are thus handled to advantage and at a less expense than by the use of horses.

The gasoline engine is taking the place of the uncertain wind mill. It is used to operate the churn, it saws wood, operates the corn cutter, and in a large number of cases it is used to generate electricity for the farm home and out-buildings. It also plows, drags, harrows, harvests, threshes and pulls heavy loads over country roads. In fact this engine is a man-of-all work.

By the aid of the engine the farmer may have a better water supply than his city relatives. For instance, an elevated storage tank will give gravity pressure for faucets or hydrants all over the farm, and the pneumatic tank, underground, gives both pressure and insurance against freezing. In the latter the engine may be used

to pump either air or water into the tank up to a pressure of from 15 to 75 pounds per square inch. It is now possible, by means of an engine, a compressed air tank and a submerged pump, to have abundant water direct from the well by simply turning a cock in the kitchen. The pump, located at least six feet under the water, may be started by turning the faucet, the air supplying power for operating the pump. A surprisingly large percentage of farm houses are being equipped with modern sanitary conveniences which contribute to the health and comfort of the family.

The gasoline engine has solved the problem of irrigation in many square miles of semi-arid territory where large projects are not possible or have been delayed. Water can often be found at a shallow depth in dry runs or by boring. A five horse power engine will raise 500 gallons per minute from a depth of twenty feet.

One of the most exhaustive chores in connection with the harvesting of the corn crop is shoveling off the load after a day of ten or twelve hours in the field. Now a two-horse-power gasoline engine, attached to a portable elevator, will empty a thirty-bushel load of ear corn into a car, corn crib or granary in from three to six minutes. The same is true to some extent of the small grain crops. Quite often both elevator and engine are mounted on the same truck, and in connection with the large threshing outfits this combination saves labor that is hard to get just at that time. The wagon is driven into position, the front wheels elevated and the rear end gate removed. The grain falls into the hopper, is elevated by an endless conveyor and delivered by a flexible spout at heights practically impossible by hand. The engine has therefore made it possible to build granaries and corn cribs

higher, at a considerable saving in initial expense per unit of storage space.

But simple and useful as this wonderful motor is, a certain amount of skill and care is required in order to obtain satisfactory results from its operation, and it is for the purpose of supplying the necessary information and rules for the guidance of the operators of these motors that the following pages have been written.

Principles of Action.—One of the greatest aids to the successful management of a gas engine is a thorough understanding of the principles controlling its action, and the nature of the fuel used in the cylinder for generating the power. Various methods are employed in the production of this explosive, power producing gas. First, there is natural gas, generated in the bosom of the earth; second, artificial gas, manufactured from coal and other substances by means of a gas producer; and third, the generation of the gas within the cylinder of the engine, by passing small quantities of the liquid fuel, gasoline, kerosene or alcohol, through a device called a mixer or carbureter, which is attached to the cylinder. The only difference between a gas engine proper and a gasoline or oil engine is, that in a gas engine, the gas is supplied to the cylinder by a gas producer, while in the gasoline engine the gas is generated within the cylinder from a charge of gasoline and exploded at the beginning of each power stroke. An engine using gas may be easily changed to use gasoline, or a gasoline engine may, by a few simple changes, be fitted to use natural or artificial gas.

The gas engine is a prime mover which derives its power or energy from the heat generated by the combus-
---thin its cylinder, of a mixture of gas and air in

the proper proportion to form an explosive. The combustion of this charge of gas and air is occasioned under a close or heavy compression, a result of the inward movement of the piston after the charge is admitted and all valves closed. The result of igniting this mixture under the heavy compression is an explosion, which is nothing more than a quick burning or rapid combustion of the mixture. This sudden explosion causes a high degree of heat within the cylinder behind the piston, and, the resultant high initial pressure against the piston drives

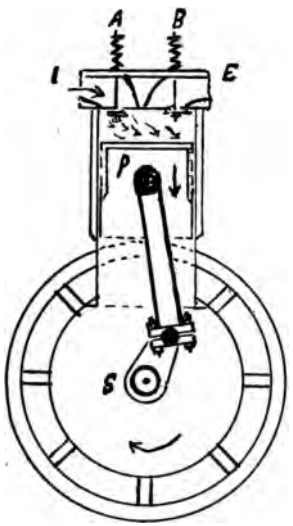


FIGURE 1.

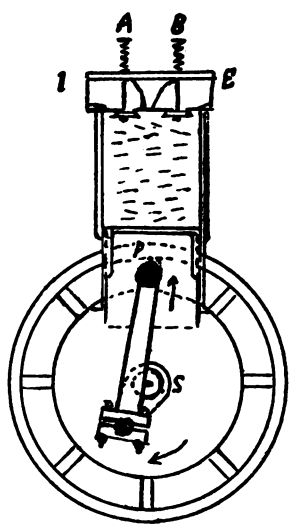


FIGURE 2.

it forward, and, through the medium of connecting rod and crank, motion is imparted to the main engine shaft.

Four-Cycle Engine.—The original gas engines, and a

majority of the smaller sizes of today, operate upon the Beau de Rochas cycle, or four-stroke cycle, sometimes termed the Otto cycle, meaning that an engine completes a cycle in four acts, defined as follows:

(1) *Induction.*—During an outstroke of the piston, see Figure 1, air and gas in suitable proportions are drawn into the cylinder. (2) *Compression.*—The following instroke, see Figure 2, compresses the combustible mixture into the clearance space. (3) *Explosion.*—Ignition of

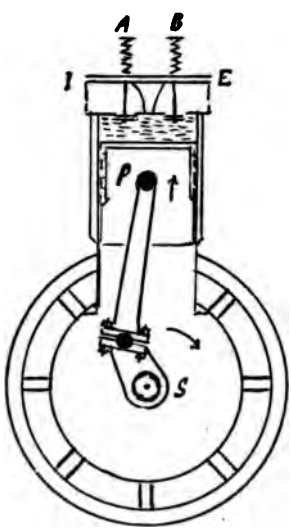


FIGURE 3.

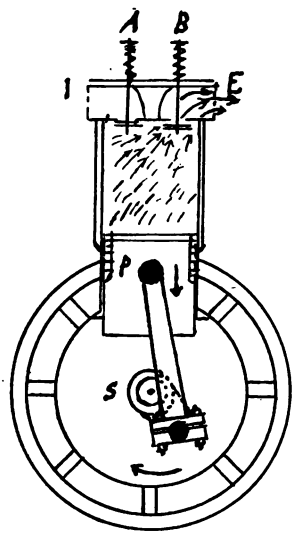


FIGURE 4.

the compressed charge causes a rapid rise of pressure and subsequent expansion of products, see Figure 3. (4) *Expulsion.*—The expanded gases are expelled by the returning piston, see Figure 4. In this type of gas engine,

two revolutions of the crankshaft are necessary in order to complete one cycle.

Two-Cycle Engine.—Many small engines and some of those of largest power are designed upon the two-stroke cycle, which is as follows: (1) Compression of the charge. (2) Ignition, explosion and expansion, and at the end of the stroke the exhaust products are expelled

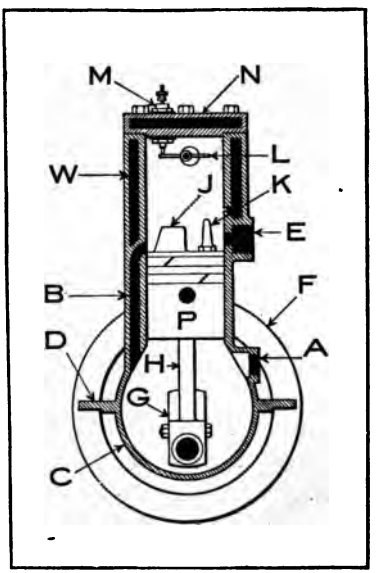


FIGURE 5.

Vertical Cross-Section, Showing the Construction of a Two-Cycle Gas or Gasoline Engine.

and the cylinder filled by a mixture of gas and air under pressure. In the two-cycle engine, two compression chambers are necessary, due to the fact that in this type

of gas engine consisting of two cylinders, either side by side, or tandem, the charge of gas and air is being received in one cylinder, while the previous charge in the other cylinder is being compressed, preparatory to explosion. A two-cycle engine thus explodes a charge, and receives an impulse at each revolution. It is important to admit only pure air and gas into engine cylinders. Dust and grit or tarry matters cause rapid wear of interior surfaces. Care is also necessary to insure the induction of cold charges, in order that maximum density of gas and air may be obtained.

Figure 5 shows a vertical cross-section of a two-cycle type of marine engine. C is the crank chamber. It has two feet, or lugs, D as shown in the drawing, for the purpose of attaching it in its postion. There is an opening at A for the reception of the mixing-valve. The flywheel F, crankshaft G, connecting-rod H, piston P, inlet-port B, baffle-plate J and exhaust-opening E, are plainly shown in the drawing.

To the top of the piston P is attached a cone-pointed projection K. This is on the right hand side and is placed there to break the electrical circuit between the contact points of the igniter. This is effected by the cone-point K striking the right hand end of the lever L, which causes the lever to rise at that end and fall at the other, thus breaking the contact between it and the insulated igniter terminal M. This breakage of the circuit causes a spark to occur between the left hand end of the lever L and the point with which it was, a moment before, in contact. This action takes place once in each revolution of the motor and just before the piston reaches the end of its upward stroke.

The ignition may be retarded or advanced by raising or

lowering the fulcrum of the lever L, by means of the eccentric shown.

The upper part of the cylinder is incased by a water jacket W, as is the cylinder head or cover N.

Figure 6 gives two diagrammatic views of the operation of a two-cycle gas or oil engine. It shows an inlet valve A, port or passage B, crankcase C, exhaust-opening E, and piston P. When the piston has reached the position shown in Diagram 1, it has forced a charge of the explosive mixture from the crankcase through the port or passage into the cylinder. The piston then moves

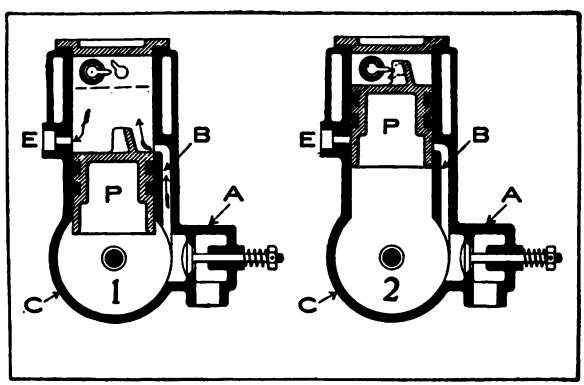


FIGURE 6.

Two-Cycle Motor Diagrams, Showing the Various Operations During the Cycles.

to the position shown in Diagram 2, and while doing so, closes the port or passage and the exhaust opening, the compressed charge is then ignited, an explosion occurs and the piston is forced out to the position shown in Diagram 1.

The admission of the new charge of explosive mixture

to the crankcase is controlled by the action of the piston. As the latter travels away from the crankcase, it has a tendency to create a partial vacuum in the latter. This operation draws the inlet-valve inward and admits the new charge.

The baffle-plate shown on the head of the piston directs the new charge from the crankcase towards the combustion chamber end of the cylinder, providing as nearly as possible a pure charge of mixture and assisting in the expulsion of the burned gases left in the cylinder from the last explosion.

As this type of engine draws in a charge of explosive mixture, compresses it, ignites it and discharges the products of combustion while the piston makes one complete travel backward and forward, it consequently has a working stroke or power impulse every revolution of the crankshaft.

CHAPTER II.

FUEL CONSUMPTION OF GAS ENGINES.

The fuel consumption, whether gas or gasoline, depends largely upon the favorable construction of all parts entering into the control and feed of the fuel supply to the engine, as well as upon the prompt and vigorous ignition of each charge, and the application of the energy resulting from it. The degree of compression which is most favorable to the fuel used in economy and power development must be carefully maintained.

The manufacturer may so construct his engines as to show a tolerably uniform result in the shop test in fuel consumption, yet, when the product of his plant is shipped into widely different parts of the country, where the climatic and other conditions are at variance with those under which the tests were made in the plant, a variable fuel consumption should be expected; in fact, is bound to be the result.

Before making a specific guarantee the manufacturer should be in position to control the conditions above referred to and the fuel used. The heat units of the fuel used determine also in a measure the quantity consumed. To show the inconsistency of undertaking to make a specific guarantee as to fuel consumption, it may be news to many to know that even the same engine under exactly the same environments and conditions and on the

same gas fuel may show a wide range of difference in quantity of fuel consumed in repeated tests.

Fuel Tests.—In sixteen tests made by Prof. Burstall at Birmingham, England, on the same engine, with illuminating gas of the town, the engine did not show the same fuel consumption in any two of the sixteen tests. The fuel consumed in the tests ranged from 20.3 to 35.1 cu.ft. per horse power per hour.

When the engine showed 20.3 cu.ft. it was developing 5.1 h.p. When it used 35.1 cu.ft. it developed only 2.52 h.p. Consequently the heavier the load the lower was the fuel consumption compared with the work done. The speed of the engine no doubt contributed to the variation in fuel used. This was only 107 r.p.m. when the engine showed the highest power and the lowest ratio of fuel consumption. While at the minimum power point and maximum ratio of consumption the engine was making 155 r.p.m.

Ordinarily it is the belief that the higher the speed the more power the engine develops, but this is not necessarily so, and may be exactly the reverse, as in this case.

These Birmingham tests show a variation in air volume from 5.3 to 10.8 of air to one of gas. The best results seem to have been obtained at 8.6 parts of air to one of gas. It is such an easy matter for an operator to change the ratio of the air and gas mixture, that here again a serious obstacle is encountered against specific guarantee.

The following figures are given by James H. Beattie is *Gas Power:*

"These figures are based on actual tests of a four-cycle engine, 7¼ in. bore by 11 in. stroke, rated at 11 h.p. at a normal speed of 290 r.p.m. The engine showed a

thermal efficiency of 24.8 per cent on test with a Proney brake. For example we will take the fuel consumption at .55 lbs., per h.p., per hour, which is near the figure actually gotten from the test. It may be said that the above engine was in perfect condition when tested, and the thermal efficiency shown by the test would seldom be equalled in every day practice. In the first place, the valves were perfectly tight, and there was no leakage past the piston. The compression at the time of the test was 70 lb. gauge. The engine itself was one of the best built today. The proportion of air and fuel was the culmination of several previous tests. In automobile and marine engines it would seldom be possible to get equal results for various obvious reasons.

"For example, we will assume that the gasoline used contained 20,000 B.t.u. per lb., at the rate of .55 lb. of fuel per horse power hour; this gives us 11,000 B.t.u. per horse power hour. Each gallon of gasoline contains 5.9 lbs., so the fuel consumption works out to a little less than one-tenth gallon per horse power hour. In other words, this engine could be operated for 10 hours on a little under 10 gallons of gasoline. In the test mentioned, the fuel consumption actually amounted to 9.5 gallons for 10 hours; the brake load showing 11.9 h.p.

"To return to the amount of fuel used at each explosion, the engine ran at 290 r.p.m., which means 145 power impulses per minute, provided every possible impulse was taken. As a matter of fact, the brake was so adjusted that the engine cut out 10 strokes per minute.

"In each cubic centimeter of gasoline, there are 50 drops under ordinary conditions. There are 3,624 C.C. in a gallon or 181,200 drops in a gallon of gasoline. At

a fuel consumption of one-tenth gallon per horse power hour or one gallon per hour for the above engine, this gives us one-sixtieth of 181,200 drops, or 3,200 drops to each minute; 3,200 divided by 135 power strokes per minute, gives us a little over 23 drops per power stroke. It should be remembered that drops of gasoline are 2½ times as small as drops of water and in comparing this with water, the figures should be divided by 2½, which gives 9+. Results for any size cylinder may easily be deduced from the above figures.

"When it comes to gas, the question is very similar. A good gas engine will consume about 15 ft. of city gas per horse power hour. Take an engine of 10 h.p., at 250 r.p.m., on full load, taking 125 explosions per minute, thus we have a consumption of 10 times 15 or 150 ft. of gas per hour. For each minute we will have 150 divided by 60 equals 2½ ft.; 2½ cu.ft. of gas are thus sufficient for 125 power strokes, or 2½ divided by 125, which gives us one-fiftieth of a foot of gas per explosion. In the case of the above engine the cylinder is 7x10 in., having a displacement of 466 cu.in., including clearance. This means that in one minute this cylinder containing 466 cu.in. must be filled with gas and air 125 times, or 33 cu.ft. of explosive mixture is required each minute. Of this 33 ft., 2½ ft. is gas and the remainder air. It might be said that in relation to the apparently small percentage of gas to air, which is usually taken at 1 to 9, that on full load the cylinder is never entirely free from burned gases when the new charge enters; so the [illegible] displacement of the cylinder is [illegible]ot taken up [illegible] hence the proportion of air [illegible] dicated in the above res[illegible] takes an interest in

very great interest. They are of value for the keeping of a close tab on fuel consumption, and consequently lead to economy. It is a very easy matter to test the fuel consumption of an engine. If gas is used, watching the meter with various settings of the air and fuel valves and keeping tab on the explosions per minute, gives a very good indication. If gasolne is used, the supply pipe may be disconnected and the connections made to a graduated cylinder temporarily. Then by trying various adjustments of the fuel and air valves, it is surprising what a saving may be made in the fuel used."

Grades of Gasoline and Fuel Oil.—Several years ago the gasoline in popular use ranged from 62 degrees to 76 degrees Baume, the greater quantity used being from 70 degrees to 74 degrees. The test has gradually declined at the rate of about 1 degree a year since then, and it is a safe prediction that the greater part of fuel gasoline sold in the next decade will run close to the lowest limit at which oil is still rated as gasoline, namely, 62 degrees Baume.

In the past the distillates just heavier than 62 degrees have been sold partly as such, partly in a mixture with lighter gasolines to make a heavier and poorer product, and partly in a mixture with heavier kerosenes to make an oil with a lower flash point, hence less desirable for illuminating purposes. Until the development of oil engines capable of using both the heavier and intermediate oils efficiently, there was no established market for the oils, which were too volatile for safe use in illumination, and too heavy for successful carburetion in the existing types of gasoline engines. For fuel purposes, the dividing line between kerosene and gasoline is rapidly disappearing. Owing to the impossibility of supplying

enough high grade gasoline to meet the demand, grade is being lowered to include a larger and lar proportion of the heavy oils, which occur in grea abundance.

Even in the face of this expedient, the proportion oils refined as kerosene and distillate is not only c running gasoline eight or ten to one, but outrunning demand for heavier oils in much greater degree. Ever ally kerosene also will run heavier, but oil as low as degrees Baume has been used successfully in a tract engine designed especially for the purpose of handl the heavy oils. The heavier the oil, the greater its h value per gallon, and the problem which automobile engine makers face is that of utilizing this heat.

For the information of those who may not be fami with the terms used to designate the various grades oil, it may be said that the gravity test involves the of an arbitrary Baume scale, graduated in reverse der from the specific gravity of liquids. The follow table shows the quality in degrees Baume at 60 degr Fahrenheit, the specific gravity as compared with wa and the weight in pounds per U. S. gallon:

Fuel	Baume Test Degrees	Specific Gravity	Wt., Per (
Gasoline	76	.679	8
Gasoline	70	.702	8
Gasoline	64	.722	6
Kerosene, 120° "Water White"	49	.784	6
Kerosene, 150° "Water White"	47.5	.789	6
Fuel Oil	35	.850	7

Many of the automobiles now on the market will h dle the lower grades of distillates without difficulty, cept, perhaps, in starting. With the present types

carbureters there will be, of course, more carbonization. To some extent this may be helped by feeding an ounce of wood alcohol into each cylinder at the end of a run, and allowing it to exert its solvent action over night. Much of the carbon will then be blown out at the next start.

All signs point to the general necessity for vaporization of the heavier oils, and manufacturers are on the alert for anything promising results in this direction.

CHAPTER III.

ALCOHOL AS FUEL.

The United States Geological Survey bulletin on "Commercial Deductions from Comparisons of Gasoline and Alcohol Tests on Internal Combustion Engines," compiled by Robert M. Strong, gives the results of tests which were conducted under the technical direction of R. H. Fernald, engineer in charge of the Producer Gas Section of the Technologic Branch at the fuel testing plant at Norfolk, Va., and in St. Louis, Mo. These tests were held to determine the relative economy and efficiency of gasoline compared with denatured alcohol. By the use of alcohol engines suited to that class of fuel as much efficiency has been obtained, gallon for gallon, as with gasoline fuel.

On this point, the bulletin states: "By using alcohol in an alcohol engine with a high degree of compression (about 180 lbs. per square inch above atmospheric pressure—much higher than can be used for gasoline on account of pre-ignition from the high temperature produced by compression) the fuel consumption rate in gallons per horse power hour can be reduced to practically the same as the rate of consumption of gasoline for a gasoline engine of the same size and speed. The indications are that this possible 1 to 1 fuel consumption, ratio by volume, for gasoline and alcohol engines, will hold true for any size or speed, if the cylinder dimensions and revolutions per minute of the two engines are the same."

Some of the more important results and conclusions stated in this bulletin are as follows:

The low heating value of completely denatured alcohol will average 10,500 B.t.u. per pound, or 71,900 B.t.u. per gallon.

The low heating value of 0.71 to 0.73 specific gravity gasoline will average 19,200 B.t.u. per pound, or 115,800 B.t.u. per gallon.

The low heating value of a pound of alcohol is approximately 0.6 the low heating value of a pound of gasoline. A pound of gasoline requires approximately twice as much weight of air for complete combustion as a pound of alcohol.

A gasoline engine having a compression pressure of 70 lbs., but otherwise as well suited to the economical use of denatured alcohol as gasoline, will, when using alcohol, have an available horse power about 10 per cent greater than when using gasoline.

When the fuels for which they are designed are used to equal advantage, the maximum available horse power of an alcohol engine having a compression pressure of 180 lbs. is about 30 per cent greater than that of a gasoline engine having a compression pressure of 70 lbs., but of the same size in respect to cylinder diameter, stroke and speed.

Alcohol diluted with water in any proportion, from denatured alcohol, which contains about 10 per cent of water, to mixtures containing about as much water as denatured alcohol, can be used in gasoline and alcohol engines if they are properly equipped and adjusted.

When used in an engine having a constant degree of compression, the amount of pure alcohol required for any given load increases and the maximum available

horse power of the engine decreases with a diminution in the percentage of pure alcohol in the diluted alcohol supplied. The rate of increase and decrease respectively is such, however, that the use of 80 per cent alcohol instead of 90 per cent, or denatured alcohol, has but little effect upon the performance of the engine; so that if 80 per cent alcohol can be had for 15 per cent less cost than 90 per cent alcohol and could be sold without tax when denatured, it would be more economical to use the 80 per cent alcohol.

In regard to general cleanliness, such as absence of smoke and disagreeable odors, alcohol has many advantages over gasoline or kerosene as a fuel. The exhaust from an alcohol engine is never clouded with a black or grayish smoke, as is the exhaust of a gasoline or kerosene engine when the combustion of the fuel is incomplete, and, it is seldom, if ever, clouded with a bluish smoke when a cylinder oil of too low a fire test is used or an excessive amount supplied, as is so often the case with a gasoline engine. The odors of denatured alcohol and the exhaust gases from an alcohol engine are also not likely to be as obnoxious as the odor of gasoline and its products of combustion.

Denatured alcohol will, however, probably not be used for power purposes to any great extent until its price and the price of gasoline become equal and the equality of gasoline and alcohol engines in respect to ability for service required and quantity of fuel consumed per brake horse power, which has been demonstrated to be possible, becomes more generally realized.

A further general development in the design and construction of engines that use kerosene or cheaper distillates, and the crude petroleum may be reasonably ex-

pected and may delay the extensive use of denatured alcohol for some time to come, but as yet comparatively few data pertaining to this phase of the general investigation are available.

The following conclusions regarding the use of alcohol as fuel for engines as compared with gasoline are based upon the preliminary results of a series of experiments conducted by the U. S. Department of Agriculture:

(1) Any engine on the American market today, operating with gasoline or kerosene, can operate with alcohol fuel without any structural change whatever with proper manipulation.

(2) Alcohol contains approximately .6 of the heating value of gasoline by weight, and in the Department's experiments a small engine required 1.8 times as much alcohol as gasoline per hour. This corresponds closely with the relative heating value of the two fuels, indicating practically the same thermal efficiency with the two when vaporization is complete.

(3) In some cases carbureters designed for gasoline do not vaporize all the alcohol supplied, and in such cases the excess of alcohol consumed is greater than that indicated above.

(4) The absolute excess of alcohol consumed over gasoline or kerosene will be reduced by such changes as will increase the thermal efficiency of the engine.

(5) The thermal efficiency of these engines can be improved when they are to be operated by alcohol, first, by altering the construction of the carbureter to accomplish complete vaporization, and second, by materially increasing the compression.

(6) An engine designed for gasoline or kerosene can, without any material alterations to adapt it to alcohol,

give slightly more power (about 10 per cent) than when operated with gasoline or kerosene, but this increase is at the expense of greater consumption of fuel. By alterations designed to adapt the engine to new fuel, this excess of power may be increased to about 20 per cent.

(7) Because of the increased output, without corresponding increase in size, alcohol engines should sell for less per horse power than gasoline or kerosene engines of the same class.

(8) The different designs of gasoline or kerosene engines are not equally well adapted to the burning of alcohol, though all may burn it with a fair degree of success.

(9) Storage of alcohol and its use in engines is much less dangerous than that of gasoline, as well as being decidedly more pleasant.

(10) The exhaust from an alcohol engine is less likely to be offensive than the exhaust from a gasoline or kerosene engine, although there will be some odor, due to lubricating oil and imperfect combustion, if the engine is not skillfully operated.

(11) It requires no more skill to operate an alcohol engine than one intended for gasoline or kerosene.

(12) There is no reason to suppose that the cost of repairs and lubrication will be any greater for an alcohol engine than for one built for gasoline or kerosene.

(13) There seems to be no tendency for the interior of an alcohol engine to become sooty, as is the case with gasoline and kerosene.

(14) With proper manipulation, there seems to be no undue corrosion of the interior due to the use of alcohol.

(15) The fact that the exhaust from the alcohol engine is not as hot as that from gasoline and kerosene

engines seems to indicate that there will be less danger from fire, less offense in a room traversed by the exhaust pipe, and less possibility of burning the lubricating oil. This latter point is also borne out by the fact that the exhaust shows less smokiness.

(16) In localities where there is a supply of cheap raw material for the manufacture of denatured alcohol, and which are at the same time remote from the source of supply of gasoline, alcohol may immediately compete with gasoline as a fuel for engines.

(17) If, as time goes on, kerosene and its distillates become scarcer and dearer by reason of exhaustion of natural deposits, the alcohol engine will become a stronger and stronger competitor, with a possibility that in time it may entirely supplant the kerosene and gasoline engines.

(18) By reason of its greater safety and its adaptability to the work, alcohol should immediately supplant gasoline for use in boats.

(19) By reason of cleanliness in handling the fuel, increased safety in fuel storage, and less offensiveness in the exhaust, alcohol engines will, in part, displace gasoline engines for automobile work, but only when cost of fuel for operation is a subordinate consideration. In this field it is impossible to conveniently increase the compression because of starting difficulties, so that the efficiency can not be improved as conveniently as in other types of engines.

(20) In most localities it is unlikely that alcohol power will be cheaper or as cheap as gasoline power for some time to come.

Cost of Fuel.—The cost of operating the gasoline farm engine is a subject that is receiving not only the attention

of the manufacturers of this type of engine but also of the different state agricultural colleges.

The following is from the pen of Mr. F. R. Crane of the Illinois College of Agriculture, and throws considerable light on the subject.

Mr. Crane says: "Considering the actual fuel used in the combustion engine while at work, there is more expense incurred than there would be in a steam engine of the same horse power doing the same work; but, for the farmer who wants a power only occasionally, and wants it quick and with small attention, the gas engine, which consumes fuel only when performing work, is far superior and less expensive than the steam engine plant, which consumes considerable fuel in getting ready for work, and which also requires the constant attention of the operator. The leading fuels used in the gas engines are alcohol, coal oil (kerosene) and gasoline.

"Alcohol can be used in the ordinary gasoline engine with a readjustment of the carbureter, allowing a different proportion of air from that used with gasoline to mix with the alcohol as it passes into the cylinder. Alcohol leaves but little deposit within the cylinder, is free from any disagreeable odor, and there is little danger from fire, but at present prices it is too expensive.

"Kerosene is a very safe fuel, but full of impurities which cause foulness within the cylinder, although this can be cared for if attended to as the occasion for cleaning arises. The present price of kerosene makes it much cheaper than gasoline.

"It is well to say here that with both alcohol and kerosene we ordinarily use gasoline to start the engine and warm it up to the point where the alcohol and kerosene will form a gas sufficient for running purposes.

"Gasoline is the present recognized fuel which is satisfactory and economical.

"As to the comparative costs of these three fuels, we find, from reliable data given out, that under average conditions about 1 pint of gasoline will produce one horse power per hour; 1.1 pints of kerosene will produce the same, and 1.4 pints of alcohol gives an equal horse power per hour, or, in other words, one horse power per hour can be produced in a gas engine by using approximately 1 pint of gasoline, 1.1 pints of kerosene, or 1¼ pints of alcohol.

"Expressed in terms of money to produce an equal power from alcohol, kerosene or gasoline, and to have that power cost the same, using as a fuel any of the three named, the ratio of their cost per gallon will be approximately as follows: If gasoline costs 14 cents per gallon, then alcohol must cost 10 cents per gallon, and kerosene 13 cents per gallon. It is a well known fact that under present manufacturing conditions alcohol must be sold for at least 30 cents per gallon. This being true, gasoline must go to 40 cents per gallon before present conditions will admit of the use of denatured alcohol.

"Experimental data brings kerosene within our reach. A few satisfactory oil engines are now offered to the trade, and the day is not far distant when the oil engine will be extensively used upon the farm."

Testing Alcohol as in a Gasoline Engine.—The following is a report of a test made by Professor Charles E. Lucke of Columbia University, regarding the use of alcohol as compared with gasoline:

The tests were made on engines intended for burning

either gasoline or kerosene. The dimensions of engine No. 1 were 5½-in. bore by 9-in. stroke and water-cooled. The compression as shown by indicator diagrams was 73 lbs. per sq.in.

The carbureter is shown in Figure 7. The governor is of the hit-and-miss type. The inlet valve is operated by suction and is not under the control of the cam at any time. The exhaust valve, however, is cam-operated by a lever. The action of the governor is as follows: When the speed gets too high, the governor prevents this valve from closing and at the same time a finger prevents the inlet valve from opening. This action results in a miss-stroke and during the miss-stroke the exhaust gases are drawn into, and expelled successively from the cylinder, whereas in some types of gas engines during a miss-stroke, fresh air is drawn into and expelled from the cylinder.

The carbureter is attached to the inlet opening, and is of the constant level overflow type, supplied by a pump.

The fuel rises through the pipe marked "fuel supply," Figure 7, over the end of which is a baffle plate to prevent splashing and surging. Any excess returns to the pump section through the overflow pipe and a cover to the chamber permits the operator to observe the level. The pump is cam-operated ordinarily, but is so arranged that it may be operated by hand in starting. The spray orifice is controlled by a needle valve having a numbered head and pointer. This needle valve is arranged to seat on the spray orifice, which is about one-half inch above the overflow pipe. The suction of the engine draws air through the air-inlet pipe, past a damper or valve for the regulation of the vacuum in the carbureter, and

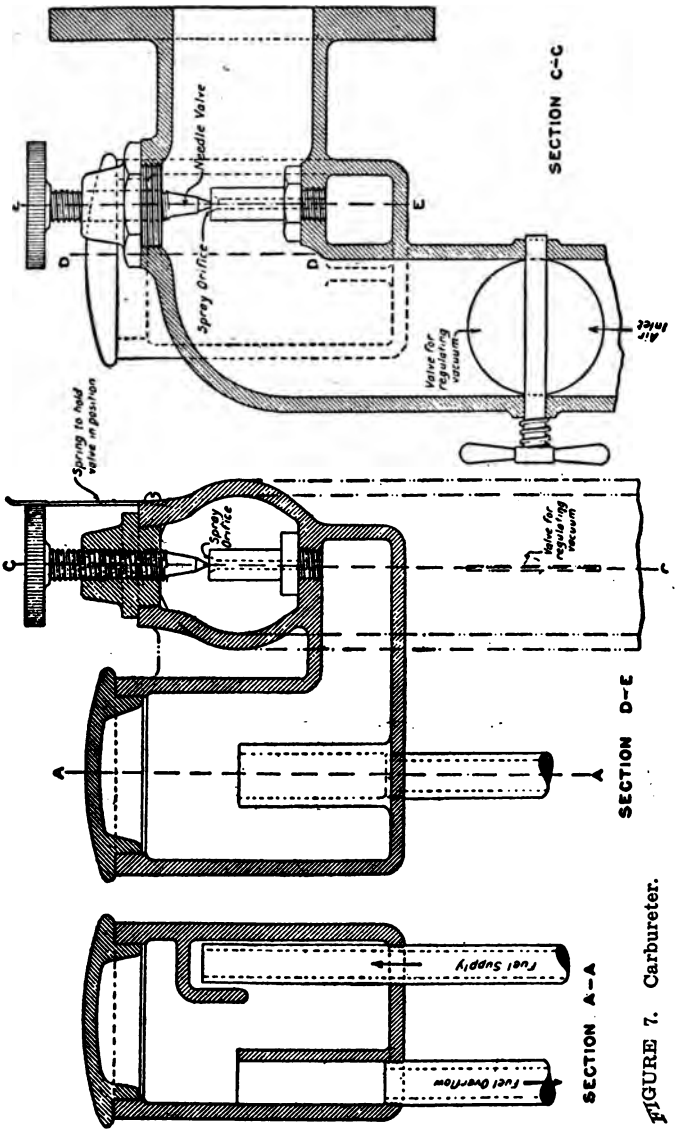


FIGURE 7. Carbureter.

thence upward to the right-angle bend across which it meets the fuel spray and passes to the engine suction. In starting the engine the piston speed is so slow, as it is turned over by hand, as to make it difficult to obtain a vacuum in the carbureter sufficient to lift the fuel the one-half inch between the overflow level and the spray orifice, and in addition spray it into the air. To make this easier, the damper or vacuum-regulating valve shown in cross-sections, is added. By closing it at the start, the vacuum may be increased and the fuel easily sprayed. All of the air used by the engine passes through the carbureter chamber and meets the spray at the orifice.

Description of Tests.—It became clear during the tests on the engine that an apparently insignificant change in the carbureter setting might possibly have a very large effect on the fuel consumption. It also became clear that the adjustment of the igniter and carbureter were matters of much greater importance in fuel economy than a considerable change in compression. To put it otherwise, increasing the compression of an engine using alcohol fuel for the purpose of obtaining a gain in economy, might be entirely useless if the engine is unskillfully handled, but in spite of considerable care in determining the best adjustment, it is not always easy to determine when it has been reached.

The operation of starting the engine was the same whether gasoline or alcohol was used as a fuel, and was no more difficult with one fuel than with the other after the proper fuel valve settings for each had been learned.

Of the fifty-four consumption tests made with this engine, twenty-four were made with gasoline as fuel and thirty with alcohol. The results are thus summarized:

Summary of Tests.—(1) With both alcohol and gasc

line fuel, from half load to full load, the best consumptions were obtained with the smallest needle-valve settings which could be used with the respective fuels and loads.

(2) With both alcohol and gasoline fuel, by opening the needle-valve the consumption could be increased to approximately twice the best consumption before the engine would be stopped by the excess of fuel.

(3) With both alcohol and gasoline, the most rapid combustion, the highest mean effective pressure and the highest maximum pressure were obtained when the fuel used was considerably in excess of the best consumption.

(4) With both alcohol and gasoline, the amount of fuel used with any given load was approximately proportional to the needle-valve setting.

(5) The minimum needle-valve setting for alcohol was about double the minimum setting for gasoline, and about equal to the maximum setting possible for the same load with gasoline.

(6) With alcohol fuel, using a slow-burning dilute fuel mixture, the consumption was perceptibly improved by using a very early ignition.

(7) The mean effective pressure, and the maximum explosion pressure were about the same for both alcohol and gasoline at best consumption.

(8) The highest mean effective pressures obtained with alcohol were appreciably greater than the highest obtained with gasoline.

(9) The maximum power obtainable from the engine was appreciably higher with alcohol than with gasoline.

(10) Much more alcohol could be supplied to the engine cylinder than would be vaporized in the carbureter, so that liquid alcohol entered the cylinder.

(11) With alcohol the engine would run on a greater range of misadjustment than with gasoline.

(12) The best consumption results obtained were 0.69 lbs. of gasoline and 1.23 lbs. of alcohol, respectively, per brake horse power hour.

(13) At best consumptions the mean effective pressures were 90 lbs. for both alcohol and gasoline.

Conclusions.—The following general conclusions are drawn as a result of the investigations not only with the engines described, but with many others:

(1) Any gasoline engine of the ordinary types can be run on alcohol fuel without any material change in the construction of the engine. The only difficulties likely to be encountered are in starting and in supplying a sufficient quantity of fuel, a quantity which must be considerably greater than the quantity of gasoline required.

(2) When an engine is run on alcohol its operation is more noiseless than when running on gasoline, its maximum power is usually materially higher than it is on gasoline and there is no danger of any injurious hammering with alcohol such as may occur with gasoline.

(3) For automobile air-cooled engines, alcohol seems to be especially adapted as a fuel, since the temperature of the engine cylinder may rise much higher before auto-ignition takes place than is possible with gasoline fuel, and if auto-ignition of the alcohol fuel does not occur, no injurious hammering can result.

(4) The consumption of fuel in pounds per brake horse power, whether the fuel is gasoline or alcohol, depends chiefly upon the horse power at which the engine is being run and upon the setting of the fuel supply valve. It is easily possible for the fuel consumption

per horse power hour to be increased to double the best value, either by running the engine on a load below its full power or by a poor setting of the fuel supply valve.

(5) These investigations also showed that the fuel consumption was affected by the time of ignition, by the speed, and by the initial compression of the fuel charge. No tests were made to determine the maximum possible change in fuel consumption that could be produced by changing the time of ignition, but when near the best fuel consumption it was shown to be important to have an early ignition. So far as tested the alcohol fuel consumption was better at low than at high speeds. So far as investigated, increasing the initial compression from 70 to 125 lbs. produced only a very slight improvement in the consumption of alcohol.

(6) It is probable that for any given engine the fuel consumption is also affected by the quantity and temperature of cooling water used and the nature of the cooling system by the type of ignition apparatus, by the quantity and quality of lubricating oil, by the temperature and humidity of the atmosphere, and by the initial temperature of the fuel.

(7) It seems probable that all well-constructed engines of the same size will have approximately the same fuel consumption when working under the most advantageous conditions.

(8) With any good small stationary engine as small a fuel consumption as 0.70 lb. of gasoline, or 1.16 lbs. of alcohol per brake horse power hour may reasonably be expected under favorable conditions. These values correspond to 0.118 and 0.170 gallon respectively, or 0.95 pint of gasoline and 1.36 pints of alcohol. Based on

the high calorific values of 21,120 B.t.u. per pound of gasoline and 11,880 per pound of alcohol, these consumptions represent thermal efficiencies of 17.2 per cent for gasoline and 18.5 per cent for alcohol.

But calculated on the basis of the low calorific values of 19,660 B.t.u. per pound for gasoline and 10,620 for alcohol, the thermal efficiencies become 18.5 for the former fuel and 20.7 for alcohol. The ratio of the high calorific values used above is, gasoline to alcohol, 1.78.

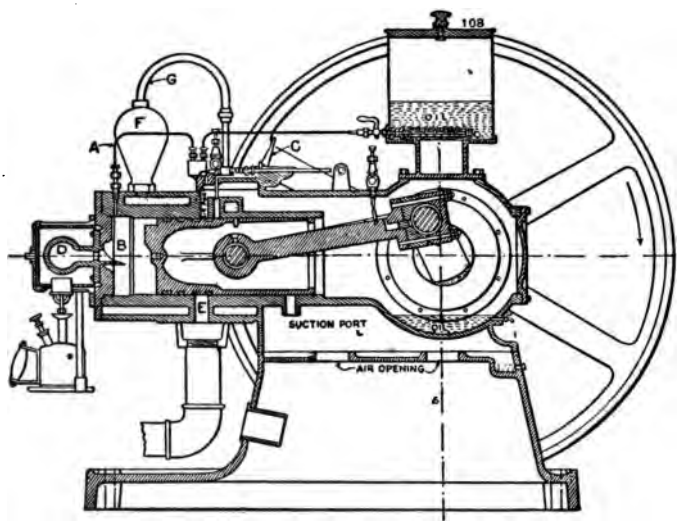


FIGURE 8.

The corresponding ratio of the low calorific values is 1.85. The ratio of the consumptions mentioned above is alcohol to gasoline, 1.66 by weight, or 1.44 by volume.

Testing Oil as a Fuel.—Figure 8 is a sectional view of one of the engines under test, and shows its working parts. This engine was tested by using oil instead

of gasoline or alcohol for fuel. It is a single cylinder, horizontal engine, two-cycle, with crankcase compression. The head-end compression, as determined from indicator cards, is 84 lbs. per square inch. It is rated at 6 h.p. at 360 r.p.m., having a cylinder diameter of 7 ins. and a stroke of 8 ins. The engine has no carbureter, but is fitted with a separate vaporizing chamber. Oil is supplied to a pump on top of the engine, which delivers it directly through pipe A to the vaporizer lip B. This pump also has a hand-operated handle C to deliver oil in starting.

When the piston moves away from the shaft two things happen. First, in the motor cylinder compression takes place; second, in the crankcase the air expands to below atmospheric pressure. When the open end of the piston reaches the port in the bottom of the cylinder, marked "suction port," air rushes in to fill the vacuum produced in the crankcase during the early part of this stroke. About the same time that compression has been completed in the head-end of the cylinder, the air has carried the liquid fuel from the vaporizer lip into the bulb D, where the fuel is vaporized, mixed with the air, and the mixture finally ignited.

Under the influence of the high pressure resulting from this explosion, the piston moves forward until the bottom of the piston on its head-end uncovers the port marked E, which is the exhaust port.

Immediately the pressure in the cylinder drops to atmospheric pressure, and the top edge of the piston moves to, and uncovers a port on the top of the cylinder, which allows the compressed air in the crankcase to rush into the head-end of the cylinder, ready for compression on the return stroke.

CHAPTER IV.

KEROSENE AS FUEL FOR TRACTION ENGINES.

Kerosene is a good power fuel when compared with gasoline (1) because it is cheaper; (2) because it is not dangerously explosive; (3) because it will not waste by evaporation, and (4) because it can be purchased of every cross-road merchant.

As a rule there is no change necessary in the engine or carbureter, both handling kerosene and gasoline alike for fuel, with the exception that for kerosene a little water sprayed with each charge into the intake or suction current aids in the ignition and combustion of kerosene, which is not necessary in the use of gasoline. Where kerosene has been tried, in many instances complaint was made of the strong kerosene odor from the exhaust which was also reported as entirely or partially overcome by the use of the water spray. With no other change to the regular gasoline equipment than the kerosene supply tank and pipe and small jet and pump for spraying a small quantity of water into each charge or suction current, the gasoline engine has been converted into a kerosene fuel engine which appears to be the equal in power development, running qualities, economy, etc., of the gasoline fuel engine.

It is better to run the cylinder from 20 to 30 degrees hotter when using kerosene, and for this reason it is often advisable to stagnate the cooling circulation to a

considerable degree. It is also generally agreed that kerosene will give better results under about 70 to 80 lbs. per square inch compression than under a lower compression. Many gasoline engines do not carry over 50 or 60 lbs. compression pressure, although a gasoline engine constructed for 70 lbs. compression will get more power from the gasoline used than when only 50 or 60 lbs. are had. A cross tee in the supply pipe next to the carbureter with one pipe leading to the gasoline tank and another to the kerosene supply tank with a shut off valve in each will enable the operator to feed gasoline or kerosene to his engine at will. It is generally the custom

FIGURE 9.

Hydrocarbon Gas Producer.

to start the engine on gasoline, since gasoline ignites more readily in a cool cylinder, and run it thus until the cylinder is well heated up, then turn on the kerosene and shut off the gasoline and the engine will usually run on without missing. When there is a little "chug" noticed in the cylinder the water spray pump may be started and by feeding this spray more or less freely the chug

may be arrested and the explosions occur as smoothly and regularly as when gasoline is the fuel.

Kerosene Gas Producer for Gasoline Engines.—Figure 9 shows a gas producer that is applicable to either stationary or traction engines, and to produce perfect combustion of the fuel, and thus insure a smokeless exhaust and clean cylinders.

This device is known as a hydrocarbon gas producer. It is cylindrical in shape, about 14-ins. long and 6-ins. in diameter. It has no moving parts, and, when once attached to the engine, becomes a permanent fixture and requires no attention whatever. When it is installed on an engine, the fuel is drawn through an atomizer and induced by the suction of the engine to go through passages heated by the exhaust, so that the action is entirely automatic and the fuel supply is in proportion to the demands of the engine under all conditions of speed and load. By means of a hydrocarbon gas producer, any two-cycle or four-cycle gasoline engine of standard make may be run with kerosene as a fuel, with perfect combustion, no increase in fuel consumption, and no decrease in power.

CHAPTER V.

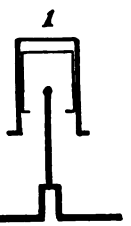
BALANCING OF ENGINES.

Engines having only one cylinder as shown in Figure 10 may be balanced to some extent by the judicious use of counterweights placed either directly opposite to the crank, or else placed opposite to the crank in the flywheels.

The effect of these counterweights is to set up an oppositely acting force which attains its maximum value at the instant the pistons and connecting-rod come to rest. Thus one force acting in one direction is made to offset another, and presumably equal force acting in the opposite direction. The result is a nullification of both forces and consequent lack of vibration of the engine frame. To this condition is added the steadying effect of very heavy flywheels which serve to absorb energy during the idle strokes of the engine. A perfect, or in fact, a near approach to perfect absorption of vibration by this means would require the engine to run at constant speed, since a change in speed changes the intensity of the centrifugal forces set up by the revolving weights, in a different ratio from the way in which the forces due to the reciprocating forces change. Consequently an engine of this type can be balanced correctly for only one speed, and will vibrate more and more as the speed varies from the standard. The difficulty in-

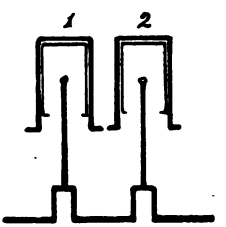
herent in the single cylinder engine has led to the general adoption of engines having two or more cylinders. In multiple cylinder engines, as they are called, the pistons and reciprocating parts can be so arranged that they move in opposite directions, and, if care is taken to make these parts of equal weight, they will counterbalance each other at any speed and thus reduce vibration to a very small amount.

This is the plan adopted in all double opposed engines of the horizontal type and is found to be quite satisfactory for all low powered engines. The pistons



No. of Cyl.	Order of Strokes			
1	P	E	S	C

FIGURE 10.



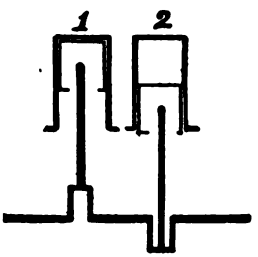
No. of Cyl's	Order of Strokes			
1	P	E	S	C
2	S	C	P	E

FIGURE 11.

are placed horizontally on each side of the crankshaft, with their open ends opposite each other. The cranks are placed 180 degrees apart, or, in other words, on exactly opposite sides of the crankshaft. Thus both pistons reach the head-ends of their respective cylinders

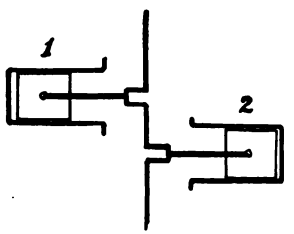
at the same instant, but travel in *opposite directions* to do so. Thus the shock occasioned by bringing one piston to rest is offset by the other.

Figures 10, 11, 12 and 13 show single-cylinder and two-cylinder crank arrangements, while Figure 14 shows a quadruple-cylinder engine with the cranks arranged in such a manner that the engine will make a power stroke



No. of Cyl's	Order of Strokes			
1	P	E	S	C
2	C	P	E	S
OR	E	S	C	P

FIGURE 12.



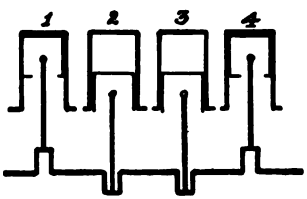
No. of Cyl's	Order of Strokes			
1	P	E	S	C
2	S	C	P	E
OR	E	S	C	P

FIGURE 13.

during each revolution. In the table accompanying each illustration, P represents the power stroke, E exhaust, S suction, and C compression. An outward stroke must be either a power stroke or a suction stroke, and an inward stroke either exhaust or compression. It will be observed that with this arrangement of cylinders a power stroke can be made to occur during each revolution, if the valves and cams are set properly. The upper set of events opposite 2 in the table under Figure 14 shows

the correct arrangement, while the lower set of events shows a faulty arrangement, since it brings both power strokes in the same revolution.

Two-cylinder engines are often placed vertically, side by side, as indicated in Figures 11 and 12. Two arrangements of the cranks are possible with this construction. They may be placed opposite or 180 degrees apart, or on the same side of the shaft in which case they are said to be 360 degrees apart. The order of strokes for both cases is clearly indicated in the figures. In Figure 11,



NO. OF CYLS	ORDER OF STROKES			
1	P	E	S	C
2	E	S	C	P
3	C	P	E	S
4	S	C	P	E

FIGURE 14.

there is a power stroke once in each revolution. The table shows an idle stroke in each cylinder between the power strokes, but in Figure 12 both power strokes occur in a single revolution, while the other revolution is idle during both strokes in the two cylinders.

In the arrangement shown in Figure 11, the recipro-

cating forces are not balanced, while in Figure 12 they are. However, of the two, the former is preferable, since it gives a steadier motion to the crankshaft and counterweights may be used to offset the unbalanced forces due to the reciprocating parts.

Of the three arrangements of the two cylinders, the horizontal double opposed is preferable, and possesses greater advantages. An inspection of the table in connection with Figure 14 will show that the order of firing is 1, 3, 4, 2 which is the way the majority of this type of engines are adjusted.

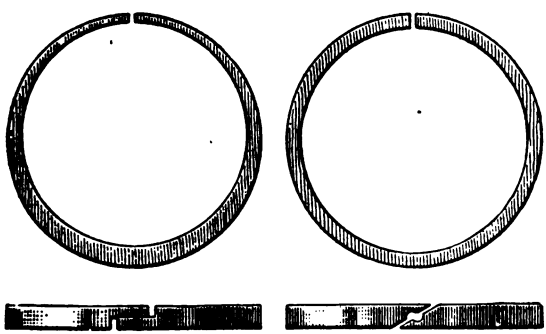
CHAPTER VI.

PISTON RINGS.

The gas engine piston, like the steam engine piston, is fitted with rings. The piston itself is of necessity smaller in diameter than the cylinder, otherwise it would be impossible for it to serve its purpose. While the piston is only a very small fraction of an inch smaller than the cylinder, from .02 to .03 of an inch, according to the size of the cylinder, this difference is quite sufficient to allow the escape of the power force unless there is provision made to close up this differencee in diameters. This, then, is the office or function of the piston rings. Usually from two to four of these rings are fitted onto the piston.

The ring is machined from a cast iron ring blank and just wide and thick enough to fit snugly into the groove in the piston. The outside diameter of the ring is somewhat larger than the bore of the cylinder so that when a piece from one-half to one inch long is cut out of the ring and the ends sprung together and the outer circumference again turned to a complete circle, it will just fit the cylinder when the cut ends are held snugly together. Then by springing the ring open enough to slip it over the piston and pushing it along until it reaches one of the grooves it will snap into the groove. Each groove in the piston is fitted with a ring in this

way. Some manufacturers think it best to let the rings play at will in the circumference of the groove, while others stay them by means of a pin fastened at a point in the center of the bottom of the groove, preferably on the under side of the piston. This pin stands up to nearly the height of the piston surface, and either a small hole, the size of the pin, is drilled into the ring, or the ends are cut in a manner to receive the pin, see Figure 16, so as to stay the ring in its groove and hold the parted ends of the ring in the same position in the cylinder circumference. The pin for each ring may be so placed as to hold the cut or open ends of the rings at a point about one-third of the circumference of the piston



Top, FIGURE 15.
Bottom, FIGURE 16.
Piston Rings.

from the several ends of the other rings. This is what is known as breaking joints and insures against a direct line of escape in case any of the ring joints should leak.

There are two methods of cutting the rings. One

makes a diagonal joint, as shown in Figure 16, the other a lap joint, as shown at the top in Figure 15. Either of these makes an effective joint, if carefully done, and not too much of the ring is cut out.

By this time it is no doubt plainly evident to the reader how the ring serves its purpose due to the fact that when the ring is first turned, its outside diameter is larger than the cylinder diameter and in this condition it could, of course, never enter the cylinder opening. To bring the diameter of the ring down to that of the cylinder, however, a piece is taken out of the ring and the ends sprung together. This reduces the ring diameter, but it also changes it from a true circle, which it was before the part was cut out and the ends pressed together, to an oval or oblong shape. Since the bore of the cylinder is supposed to be a true circle, something else is necessary to make the ring fit the cylinder. Consequently, all manufacturers who want to make their rings most effective clamp the rings with their ends together and turn their outer circumference again to a true circle so that its diameter is but a very small fraction less than that of the cylinder. By this means a perfect ring with an outward spring is made, which fits snugly to the walls of the cylinder when it is adjusted to the piston groove. It is therefore readily seen how such rings will fit the cylinder so snugly as to close up any space between piston and cylinder walls and thereby prevent the escape of the explosive force and help in distributing the lubricating oil to all parts of the cylinder.

Two styles of rings are shown in Figure 15; one being of uniform thickness and the other extra heavy on the bottom.

Properly working piston rings are fuel and power savers. Improperly working rings are wasteful both of power and fuel, as well as lubricating oil, which often results in serious damage to the cylinder. It is therefore important to keep ring grooves clean and the rings working perfectly.

CHAPTER VII.

VALVES.

A valve in a very bad or pitted condition causes bad compression and the exhaust valve should be ground occasionally. After grinding a valve be sure that there is ample clearance between the valve and the lifter. It should have not less than one-thirty-second of an inch, otherwise when the valve becomes hot it will not seat properly, poor compression being the result. In grinding a valve there is no occasion to use force, and the grinding should be done lightly, the valve being lifted from time to time so that any foreign substance in the emery will not cut a ridge in the seat or the valve itself. After grinding a valve always wash out the valve seat with a little kerosene and be careful that none of the emery is allowed to get into the engine cylinder.

Sometimes an engine may suddenly stop from the failure of a valve to seat properly. This may be due to the warping of the valve through the engine having run dry and become hot, or it may be from the failure of the valve spring or the sticking of the valve stem in its guides. The valve should be removed and the stem cleaned and scraped, or straightened if it requires it, until it moves freely in the guide, and the spring is

given [illegible]
the [illegible]
valve [illegible]

Valves [illegible]
in place [illegible]
and [illegible]

[illegible]
inlet and [illegible]
diameter [illegible]
per [illegible]
is made [illegible]
chamber [illegible]
at small [illegible]
the valves [illegible]
any case [illegible]
to the [illegible]
ports being [illegible]

In engines [illegible]
chamber is [illegible]
tains its [illegible]
seats being [illegible]
wise [illegible]

When the [illegible]
erated, it is [illegible]
during the [illegible]
inlet and [illegible]
such a [illegible]
the cylinder is [illegible]
the exhaust [illegible]
about [illegible] ft. per [illegible]

Diameter and [illegible]
diameter of inlet [illegible]
of the valve [illegible]

valve opening, the following formulas will be found useful:

Let B be the bore of the motor cylinder in inches, and S the stroke of the piston also in inches. As R is the number of revolutions per minute and D the required diameter of the valve opening, then

$$D = \frac{B \times S \times R}{15{,}000}$$

Example: Required the diameter of the admission-valve opening for a motor of 6-in. bore and 9-in. stroke at 600 r.p.m.

Answer: As 6 multiplied by 9 and by 600 equals 32,400, then 32,400 divided by 15,000 gives 2.16 ins. as the diameter of the valve opening.

The lift of the 45-degree bevel-seat form of valve requires to be about three-eighths of the diameter of the valve opening: that is, if L is the required lift of the valve and D the diameter of the valve opening, then

$$L = \frac{D}{2.83} = 0.35\ D$$

The bevel-seat form of valve is to be preferred to the flat-seat or mushroom type of valve, for two reasons; first, that it is more readily kept in shape by re-grinding, and second, it gives a freer and more direct passage for the gases.

For an atmospherically operated admission-valve which will insure practically a full charge in the motor cylinder the formula should be

$$D = \frac{B \times S \times R}{12{,}750}$$

Both inlet and exhaust valves should be of ample area and short lift, and be arranged so that they may be readily inspected and adjusted, and with as few joints as possible.

Valve Lifters.—Figure 17 illustrates a form of valve operating mechanism in which the valve is actuated by means of a roller upon the end of a rocker arm, to

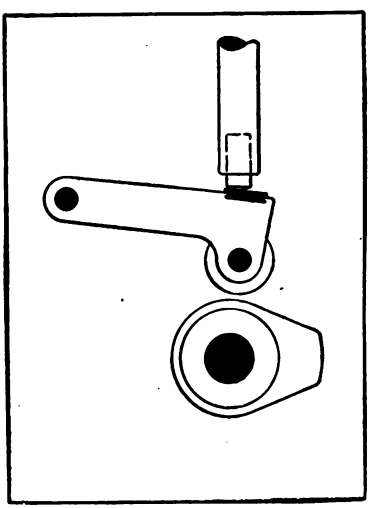


FIGURE 17.

Valve Lifter and Roller Lever with Hardened Steel Lifter Plate.

the upper side of which is secured a hardened steel plate, which in most cases acts directly upon the end of the valve stem.

Another form of valve lifter is shown in Figure 18 in which the rocker arm is omitted, the cam operating the valve through the medium of a plunger rod and roller.

Valve Operating Mechanism.—A form of valve operating mechanism is shown in Figure 19, in which both the inlet and exhaust valves are operated independently by means of a rocker-shaft and lifting-arms, through the medium of two cam-rods and levers shown at the right of the drawing. The lifter-arm and cam-rod lever of the inlet valve are in one piece, and work free on the end of the rocker shaft.

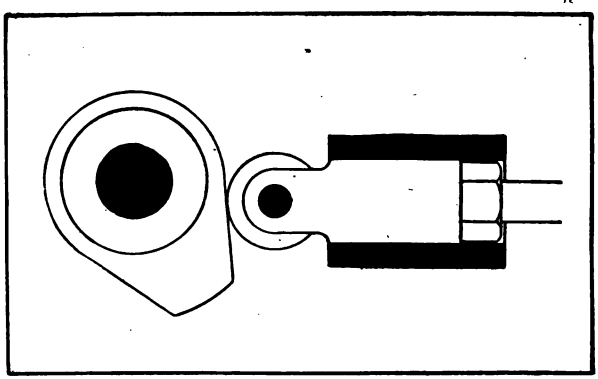


FIGURE 18.
Valve Lifter with Cam Acting Directly on the Lifter.

Fit of Valve Stems.—The inlet and exhaust valve stems should not be a very close fit in their guides. If the fit in these guides is made too close, when the valve chamber becomes heated the consequent expansion may cause the valve stem to stick in the guides and leakage of the valve will result.

The valve seats are in some engines left almost sharp, being not more than one-sixteenth of an inch wide before grinding.

Timing of Valves.—The movement of the valves should

always be timed to give the proper results. This is an important point to remember. The camshaft on a four-cycle engine is usually driven by the two to one gear on the crankshaft, and if for any reason the gears are taken apart and put together, with only one tooth out of place, it will throw the valve mechanism out of time.

To ascertain if the valves of an engine are properly

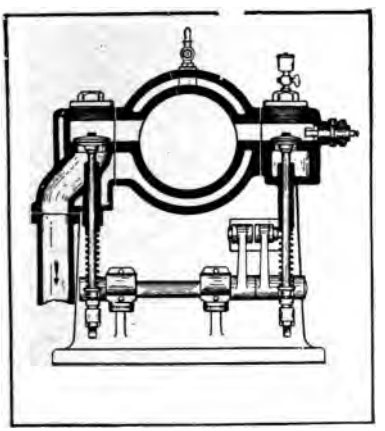


FIGURE 19.

Valve Operating Mechanism, Showing Inlet and Exhaust-Valves and Lifter Rods.

timed, turn the flywheel over slowly and notice at what points the valves open and close, and when the ignition, if electric, takes place.

The exhaust valve should open when about five-sixths of the stroke is completed and close at the end of the next stroke. The next inward stroke is the compression stroke, when all valves should be closed. At the beginning of the next outward stroke the inlet valve should be slightly open.

If the engine is taken to pieces, it is important that a tooth of the gear wheel on the crankshaft and a corresponding space of the gear on the camshaft should be marked, so that when put together again the same teeth may mesh together, and so avoid altering the throw of the cams and consequent timing of the valves.

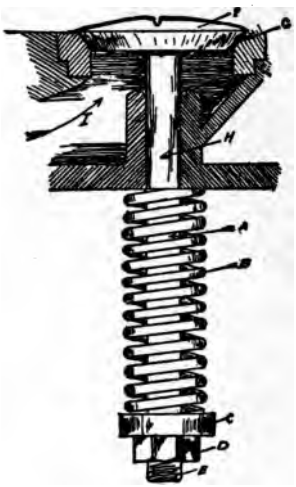


FIGURE 20.

Valve Troubles.—Some of the things that may happen to the valve are: A warped disk, F, Figure 20, which would prevent the valve from seating properly; thus the compression would escape past to the exhaust. The valve stem, H, may become carbonized and fail to work free in the guide, in which case it will stick part way open and the engine will have little or no compression. The valve stem should not be oiled, because of the great amount of heat it is subject to. The oil will burn and

carbonize and in a very short time the valve will fail to work. The valve spring needs attention as well as the valve itself. It, like the valve, is subject to a certain amount of heat and after a time will lose its tension and fail to cause the valve to seat properly. In this case the spring must be replaced with a new one, but if no new one is at hand the old one may be taken off and stretched until it gives the required tension. A point which affects power and must not be overlooked is the distance between the valve stem and the lift. In case the valve lift should not raise the valve high enough to allow a full charge to enter the cylinder, or the burned charge to be driven from the cylinder the engine would run very well when empty, but when the power was applied would die down at once.

CHAPTER VIII.

LEAKY PISTONS.

Leaky pistons are not only annoying, but exceedingly wasteful of fuel and power. In a closed base engine, such as a two-cycle or multiple cylinder automobile motor, it is not always easy to determine where the trouble is and what is the real cause of it. A leak past the piston may result from ill-fitting rings, or from clogged rings, from a scored or scratched cylinder wall, from a puncture in the piston walls or in the head. Whatever the cause, much damage may finally result if allowed to continue any length of time. When a leak by any portion of the piston wall occurs it not only allows the escape of the expansive force, but it also causes a prompt drying up of the lubrication along the overheated path of the escape. And the moment lubrication is checked and becomes ineffective scoring of the cylinder is liable to begin. And when the friction once becomes so great that the walls of the cylinder begin to cut or score they will be quickly damaged and often beyond repair.

A leak resulting from poorly fitted piston rings may be distinguished by dark colored sections along the course of the outer circumference of the ring. A ring that fits the cylinder perfectly is bright and smooth in its entire circumference. But one that is bright only in spots on its circumference, in reality, only touches the walls of the cylinder in spots. This indicates that either

the cylinder is not round or that the rings are not properly fitted to the cylinder.

In boring out a cylinder, by the dulling of the tool, as it takes its cut from one end of the cylinder, it may leave the end where the cut is finished smaller than the other. Consequently a piston and rings that will fit the small end will be too small for the other end of the cylinder and will therefore usually allow the escape of the explosive force. A cylinder should not only be a true circle on its interior diameter, but the circle should be of exactly the same diameter from end to end. Probably next to imperfect fitting rings and cylinder diameter the clogged ring gives most trouble.

Burnt carbon from a poor quality of lubricating oil or from too free use of oil or rust or dirt of any kind that becomes baked onto the rings may cause them to stick tight in their grooves and thus become entirely inactive and useless. Sometimes this condition may be helped and apparently overcome entirely by injecting kerosene into the cylinder. This has a tendency to dissolve and soften up the baked carbon which is gradually gotten rid of by flushing itself out of the cylinder with the surplus kerosene. But many times it is necessary to remove the piston from the cylinder and saturate it in kerosene until the rings get loose and can be lifted from their grooves and be thoroughly cleaned by scraping and washing with kerosene or gasoline. The grooves in the piston should receive the same treatment before the rings are replaced in them.

A puncture in the piston walls or head usually results from a sand or blow hole in the casting, or if pins are used in the ring grooves to stay the rings, the pin hole may extend through the piston wall at the bottom of the

groove and when the pin gets loose and drops out there is a leak hole through the bottom of the ring groove. The indications of a leaky piston are: Low compression, loss of power and a blowing sound in the crankcase when the piston is moving in on its compression stroke. The correction of the cause, in a leaky piston, promptly, will save much worry, fuel, and often much unnecessary expense.

CHAPTER IX.

THE CYLINDER.

Cylinder Construction.—Cylinders made with a loose head require the joint to be made with great care. An asbestos or copper ring is used to make this joint and sometimes wire gauze with asbestos is used.

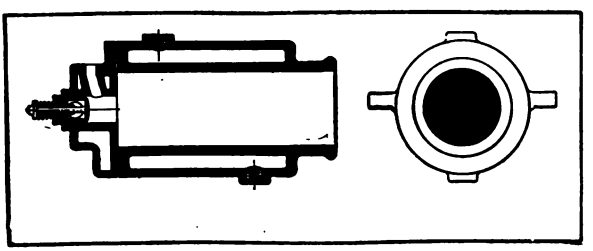


FIGURE 21.

Gas or Gasoline Engine Cylinder, with Detachable Water-Cooled Head.

Figure 21 shows a cylinder with a loose water-jacketed head in which both the inlet and exhaust valves are located. This style of cylinder has feet, or lugs, on either side to attach it to the bedplate.

A form of cylinder is shown in Figure 22 in which the cylinder and head are cast in one piece. It has a separate valve chamber (not shown) which bolts on the side of the cylinder and communicates with the combustion chamber by a port or passage shown in the

drawing. This style of cylinder is attached to the bedplate by means of a circular sleeve which fits into an opening at the end of the bedplate and is drawn up against the circular flange shown by means of bolts.

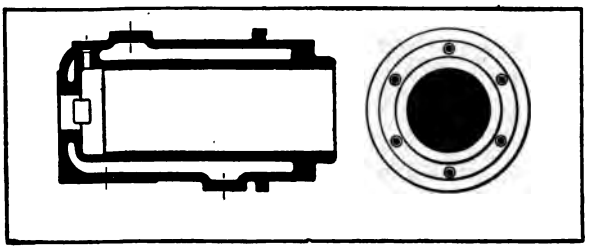


FIGURE 22.

Gas or Oil Engine Cylinder, with Cylinder and Head Cast Integral.

Cylinder Boring.—A good way to bore a cylinder is to make a boring-bar to fit in the drill socket of a back-geared drill press and a brass or phosphor bronze bushing to fit in the center hole of the table of the drill press. The cylinder can be clamped to the table of the drill press by its flange and bored out with a cutter set in the boring-bar. Not less than three, and preferably four cuts, should be taken to make a good job. A mandrel should then be made with two flanged hubs, one of which should be fastened to the mandrel and the other turned slightly taper so as to make a snug fit in the cylinder bore when in place. The ends of the cylinder can then be finished on the mandrel and a perfect job will be the result. In case a back-geared drill press is not handy the cylinder can be clamped to the carriage of the lathe, bored out with a bar in the lathe centers and the ends finished in the manner above described, but it is a much slower job than in a drill press. The

cutter for the bar should be made from a piece of round tool steel not less than five-eighths of an inch diameter. It can then be readily adjusted to any desired angle to obtain the best cutting effect.

Cylinder Sweating.—Sometimes water will collect in the cylinder as a result of the interior walls of both the cylinder and cylinder-head sweating. This, however, does not often happen except on very warm days when a considerable volume of cold water has been allowed to flow through the water-jacket after the engine has been shut down, and this seldom applies where the thermo-syphon water-cooling system is used. It is more liable to happen where the cold water from a hydrant has been allowed to flow through the water-jacket.

CHAPTER X.

THE CARBURETER OR MIXER.

The principal difference between the gas engine and those engines, such as gasoline, oil, etc., that use a liquid fuel is, that with the latter the gas is generated within the engine itself while in operation, while with the former the gas is supplied from outside sources.

In early gas engine practice a gasoline or oil vapor gas was made by passing air in close proximity to a large surface of the liquid fuel. The air was thus saturated with the vapor of the gasoline or oil, and became a vapor gas similar to artificial or natural gas. This vapor gas was piped to the engine and mixed with air in proper proportion to secure the quickest and best combustion. This principle of mixng is used now with natural, artificial and producer gas. The next development in the use of liquid fuel was the mixer, or carbureter, by which a minute quantity of the gasoline or oil is measured and supplied with each charge of air entering the engine cylinder. With the stationary, single cylinder, industrial engines in common use the device for measuring the liquid fuel is called a mixer, and is usually made a part of the engine. A gasoline or fuel pump and constant level overflow cup is provided so that the gasoline tank may be located outside of the building in compliance with insurance regulations about the storage of gasoline.

For multiple cylinder, and lighter engines the measuring device is called a carbureter, and is generally an accessory to the engine.

Figure 23 shows the principle of the constant level overflow mixer system, commonly employed in the single cylinder stationary engine. A is the constant level overflow cup, showing how the gasoline or liquid fuel rises in the spray nozzle, F, to the same level maintained in the cup. B is the pipe from the gasoline pump, and C is the overflow pipe that leads the surplus gasoline back to the tank. D is the gasoline regulator, E the air regulator, F the spray nozzle and G the short passage

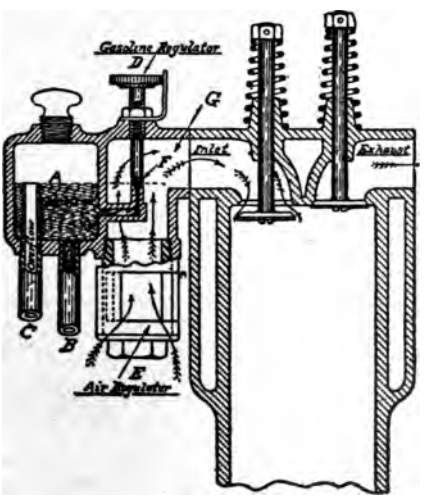


FIGURE 23.

to the inlet valve of the engine. At a given speed the engine draws in a certain amount of air by the regulator, E. The air rushing past spray nozzle, F, draws a small quantity of gasoline, measured by regulator, D, from the

spray nozzle, and carries it into the cylinder of the engine. The natural heat in the air supply, assisted by the heat of the cylinder, turns the gasoline spray into a gas that burns like a flash or "explodes" when compressed and ignited by the engine, provided of course that the right proportion of air and gasoline has been obtained. This is easily known by adjusting the fuel and air regulators, and observing the action of the engine, especially under load. The greatest amount of air with the least

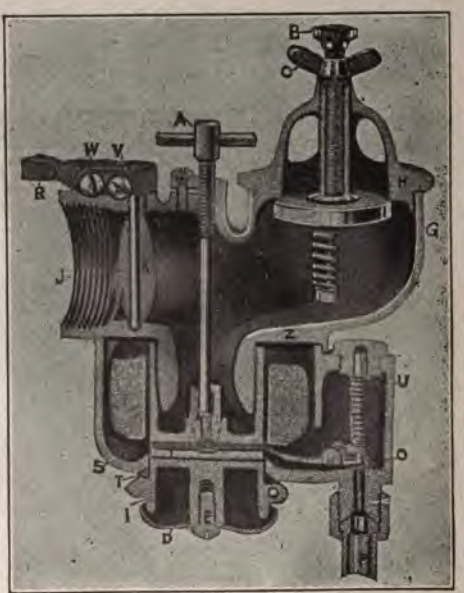


FIGURE 24.

amount of gasoline for the strongest pull at a given speed will be the correct position for the regulators. For easy starting the air regulator should be closed a little, then opened again when the engine gets up speed.

Figure 24 is an illustration of an accessory carbureter, such as is commonly used on multiple cylinder and light motors, although it is applicable to any type of engine. A float, M, controlling a valve, O, takes the place of pump and overflow system shown in Figure 23, maintaining a constant level of the fuel in the spray nozzle, L. The float chamber is placed around the spray nozzle so that in traction or marine work, involving various angles and positions of the machine, there will be no variation of the fuel level in the spray nozzle. The fuel tank is usually placed above the carbureter, and connected by pipe P to float valve O. The liquid fuel is thus fed to the float chamber by gravity. By using a light air pressure in the tank it may be placed below the carbureter, but this is not often done. The mixer shown in Figure 23 is designed for a given engine speed. If the engine speed is changed the air and gasoline regulators must also be changed to get the best results. The carbureter is generally designed to automatically adjust itself to a considerable range of engine speed. Thus in Figure 24 the air for starting and slow speed enters at I. As the engine speed increases the compensating valve, G, opens, more air is admitted and the syphon force exerted on the spray nozzle, L, is kept in fairly accurate proportions to the requirements of the engine.

K is a butterfly throttle valve for governing either automatically or positively the amount of mixture admitted to the cylinder, and thus controlling the speed and power. Some makers connect the needle valve, A, to the throttle lever, R, in such a way that on full open throttle the needle valve is given additional opening. Other designs like the one illustrated in Figure 24 depend entirely on

the compensating valve for the proportion of liquid fuel and air, covering the range of speed and power required of the engine. Aside from the differences in regulation and control, the essential principles of the overflow and float feed systems are practically the same.

Figure 25 illustrates the principle of the generator or mixing valve, a very common method of measuring the

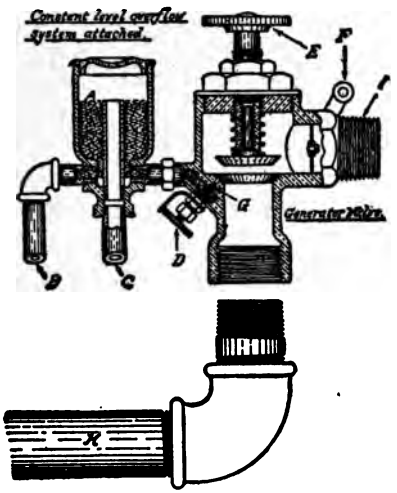


FIGURE 25.

liquid fuel for making each charge of gas for a gas engine. The liquid fuel (generally from a tank higher than the valve) is supplied to the fuel regulator, D. When the intake stroke of the engine draws air through the valve a small quantity of gasoline or fuel oil, measured by regulator D, is drawn from the drilled opening to the valve seat, G. When not in action the valve is held to its seat by a light tension spring, thus preventing

cup to hold a small amount of gasoline for heating the intake pipe for easy starting in cold weather.

The higher the speed of the engine the less time there is for the thorough gasification of the measured liquid for each charge. The heat of the cylinder has less effect. The use of multiple cylinders has brought greatly increased practical speeds. These facts, together with the

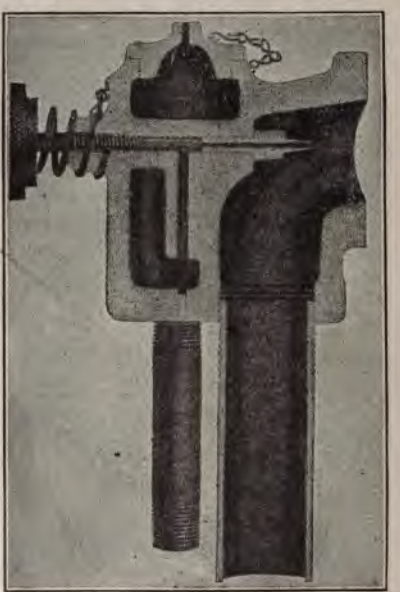


FIGURE 26.
Simple Mixer.

very desirable purpose of serving each cylinder of an engine with an equal quantity of an equally carbureted mixture, seems likely to bring further improvements in gas generating devices for liquid fuel. The present practice is to put the measuring mixer, carbureter or

generator valve, as the case may be, as close to the cylinder intake valves as possible, and depend principally on the heat of the cylinders for completing the gasification. A complete gasification of the charge before it reaches the cylinders would certainly add to the fuel economy, smoothness and reliability of action in high speed multiple cylinder engines, if it can be accomplished in a practical way, and without possible ignition of the mixture in the carbureter and intake manifold.

Types of Carbureters.—There are many different devices for evaporating the fuel oils, and they range from the simple mixer shown in Figures 25 and 26 to the

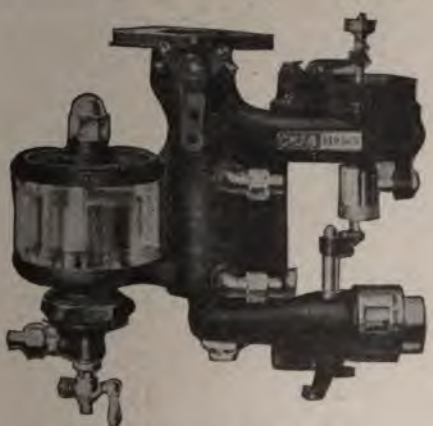


FIGURE 27.
Carbureter.

elaborate carbureter shown in Figures 24 and 27. The mixer may be built along lines of very rigid simplicity, consisting of but few parts; while on the other hand the carbureter consists of an aggregation of parts, both moving and stationary, all requiring proper adjustment.

The easiest service for a carbureter is that required by a single cylinder stationary engine operating on a constant load. The most exacting service is that on an automobile where both the loads and speeds are variable, and all kinds of roads are traveled.

Action of Carbureters.—One of the first requirements of a carbureter is to deliver the oil automatically, to suit

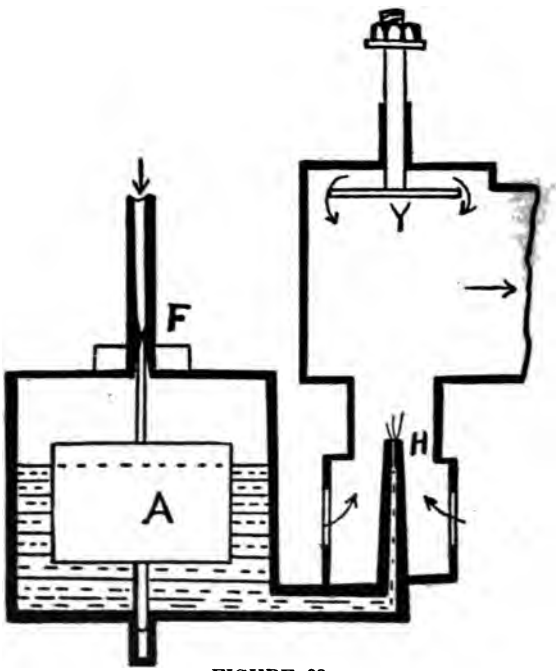


FIGURE 28.
The Principle of the Float Feed Valve.

variable loads and speeds, with the vehicles on various grades, and when tilting sidewise; also, the carb must not be affected by the vibration of the vehicl

general method by which the oil is kept at a constant level in the carbureter is by the use of a float-feed valve. The principle of this valve is shown in Figure 28. The float valve A is in a separate chamber from the body of the carbureter. The float is made of sheet copper and is lifted by the oil in the reservoir so as to shut off the supply by the needle valve F. The height of the oil is kept at a level about from one-eighth to three-sixteenths of an inch below the spray nozzle H. A modern carubreter using the float feed is shown in Figure 27. A sectional view of this carbureter is shown in Figure 29. In this make the needle valve is below the

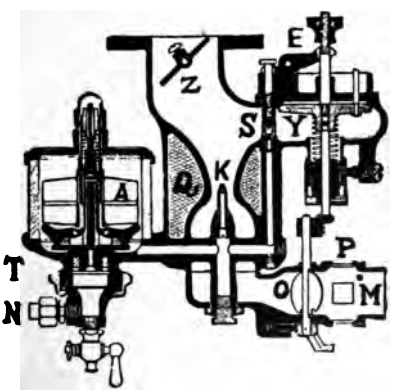


FIGURE 29.

In This Carbureter the Needle Valve is Below the Float and is Closed by a Spring.

float A, and the gasoline connection is at N with a strainer T. Where the needle valve is below the float, the valve must be closed by its own weight or by a spring as in Figure 29. The weight of the float operates

on a pair of levers when it settles down, lifting the valve and admitting more oil. This construction is shown in Figure 30. The weight W presses the valve to its seat when the float A is clear of the levers H. When the oil level lowers, the weight of the float resting on the outer ends of the levers lifts the valve.

In addition to the float feed, the carbureter shown in Figures 27 and 29 has special features to meet the requirements of variable speeds and loads. The spray

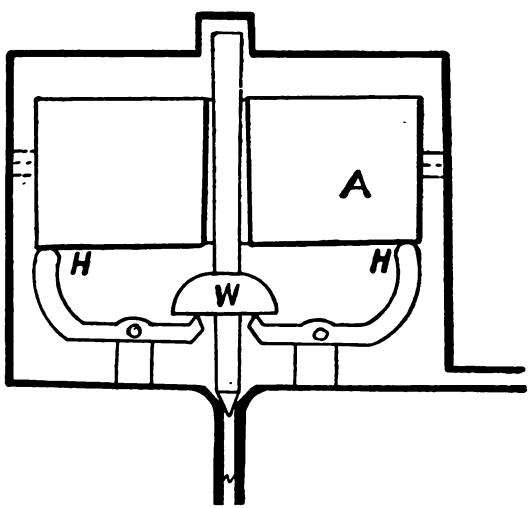


FIGURE 30.

The Needle Valve in This Case is Weighted and is Raised by the Float Acting Through Levers "H."

nozzle K is central and stands vertically in the air tube where the oil is atomized. The air supply enters through the openings around the horizontal tube M. The size of these openings is regulated by a concentric slide P, and

a butterfly valve O is used in a hot air connection to this tube. There is also a second spray nozzle S, and a second air intake at Y. A throttle valve is located in the vapor delivery tube Z.

The use of a second spray nozzle and air inlet forms a special improvement on carbureters for high speed service. It is thought impossible to make a carbureter with a single air inlet that will supply vapor for all speeds of the engine. Hence, the method of construction is to make and adjust the lower inlet for low engine

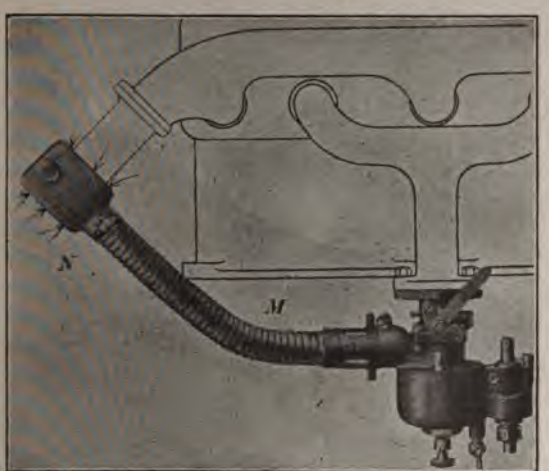
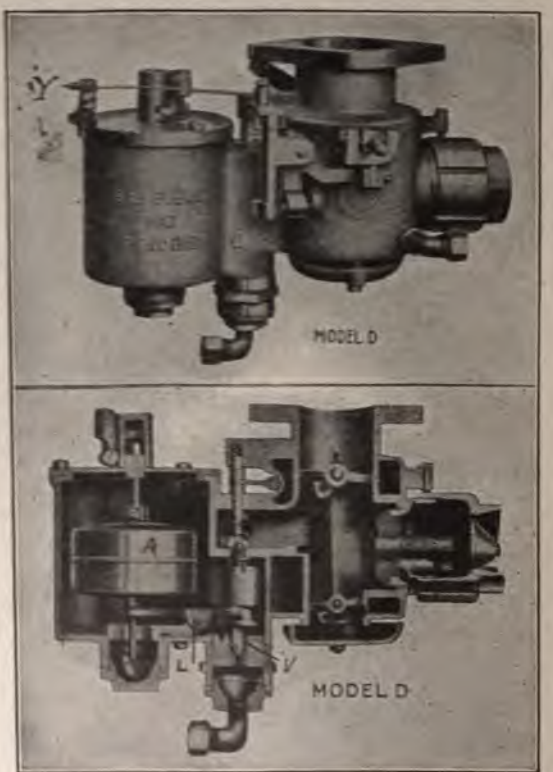


FIGURE 31.
Carbureter with Hot Air Connection.

speeds, as at M, Figure 29, and the second inlet for high speeds. The way in which these two air inlets work together and automatically is interesting. In the first place, it must be understood that a gas engine requires a richer mixture for low speeds, as at starting,

than for high speeds. By locating the second air inlet above the spray nozzle, the vapor is made lean. This is desirable because a weak mixture burns faster than a rich one. At low speeds and when under heavy loads,



Top, FIGURE 32.
A Carbureter with Adjustments Designed to Take Care of Any Speed or Any Atmospheric Condition.

Bottom, FIGURE 33.
Sectional View of Figure 32, Showing Interior Construction.

a rich mixture is desirable, because it is slow burning and keeps up a higher working pressure during the stroke.

Adjustments of the various springs, levers and valves are made so that the engine gets its entire supply of oil vapor from the central nozzle K and the air from the lower tube up to about 600 r.p.m. A further increase of suction from a higher speed will open the auxiliary air valve Y. As this valve is connected to the upper spray nozzle S by the lever E, the second spray nozzle begins to operate with the extra air supply. A water jacket Q surrounds the vapor chamber. Hot water from

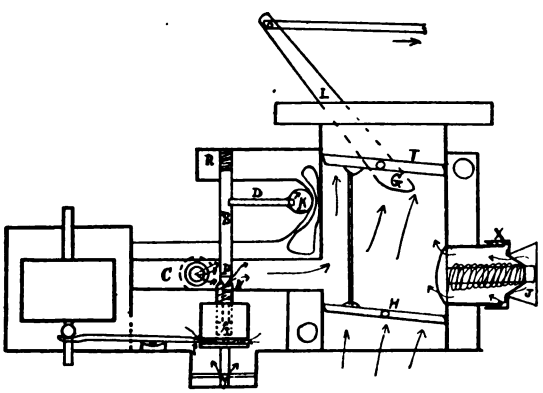


FIGURE 34.

Detailed View of the Three Air Inlets of Figure 32.

the engine jacket is piped to the carbureter, the connections L and G being for this purpose. There is a hot air connection at O so as to insure heated air for vaporizing the oil. The air is heated by arranging a sleeve N around the exhaust manifold of the engine, as shown

in Figure 31. The sleeve is connected by an armored tube M to the carbureter, and conducts the air to the vaporizer chamber.

Another type of float feed carbureter is shown in Figures 32 and 33. In this example the copper float

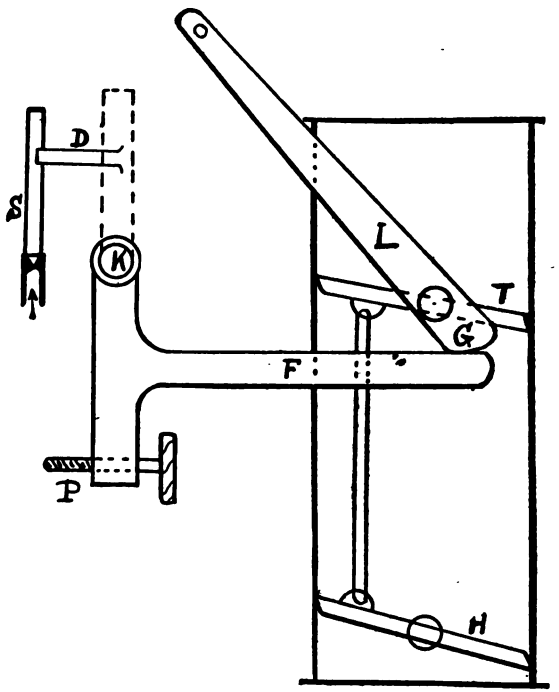


FIGURE 35.
The Throttle Control of Figure 32.

A, Figure 33, operates a weighted lever—valve V—by resting on a lever L. The lifting of the float allows the weight to seat the valve V and shut off the oil. The characteristic features of this carbureter are the three

air inlets, the mechanically operated air valve and spray nozzle, together with a fixed open air nozzle and an automatic one. This carbureter also has three adjustments. At first sight one is bewildered by this great array of mechanical combinations, but the method of operation is single. This example shows, however, the great ingenuity displayed by inventors to produce a perfect mixture of gasoline vapor and air at all engine

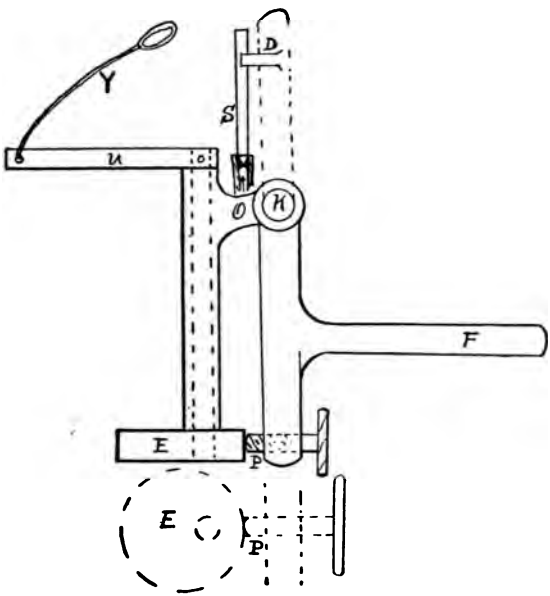


FIGURE 36.

Connections for Operating the Spray Nozzle from the Dash.

speeds and under all conditions of atmospheric humidity.

The lower air-intake has a butterfly valve H linked to the throttle valve T of similar design (see Figures 34, 35 and 36 for use of reference letters). Hence, when the throttle is opened, the air valve H also opens. The

automatic air intake has a conical valve J, which is held to its seat by a spring. The suction of the engine at high speed causes this valve J to admit additional air. The tension of the spring is regulated by the screw sleeve X that is turned by hand. The spray nozzle is at N and it is closed by the needle valve P having a long vertical stem S. There is a venturi air tube C through the side of the carbureter opposite the spray nozzle. This opening is not shown in Figures 32 and 33, but will be seen in the diagram Figure 34. The spray valve is kept closed normally by a spring R pressing against the upper end. By a system of levers and cams, this spray valve is connected to the throttle valve stem and it is moved in conjunction with it. There is also a second system of levers by which the spray valve can be operated independently of the throttle connection by the wire Y, Figures 32 and 36. In auto service this wire extends to a button on the dash.

Details of the working parts of this carbureter are illustrated diagrammatically in Figures 34, 35 and 36. The throttle lever L has a cam G on the lower end. As the throttle opens, the cam G forces the lever F, Figure 35, downwards and turns the supporting shaft K to the right. This shaft carries a projection D (also shown in Figures 33, 34, 35 and 36) which engages a slot cut in the side of the spray valve stem S. Hence, the turning of the shaft K to the right lifts the spray valve. On the shaft K is another lever O, Figure 36, having a vertical shaft turning through it. At the top of this horizontal shaft is a lever U to which the operating wire Y is attached, and at the lower end is a cam E. The pulling of the wire, therefore, turns the cam E against the end of the adjusting screw P, forcing

the lever O to the left and turning the shaft K to the right as before, and opening the spray valve S. The purpose of the second motion of the spray valve is to make it possible to admit more gasoline without change of throttle.

Non-Adjustable Carbureter.—It will have been noticed in the foregoing descriptions of carbureters that each of the examples has various adjustments made by

FIGURE 37.

A Modern Carbureter Having no Spring or Lever Adjustments.

levers, screws, springs, valves, etc. This would indicate that the service to which a carbureter is subjected is varied, and that the builders of them are endeavoring to accommodate all the demands of the trade. It is interesting to note, however, that the solution of the problem of the adjustments has been attempted by building a

carbureter having no adjustments. One form of this type is shown in Figures 37, 38 and 39.

It will be seen from the sectional view, Figure 38, that this particular make has a float feed, but that the levers operating the needle valve B are above the float and they close the valve from the flotation effect of the oil on the float. The spray nozzle C delivers the oil

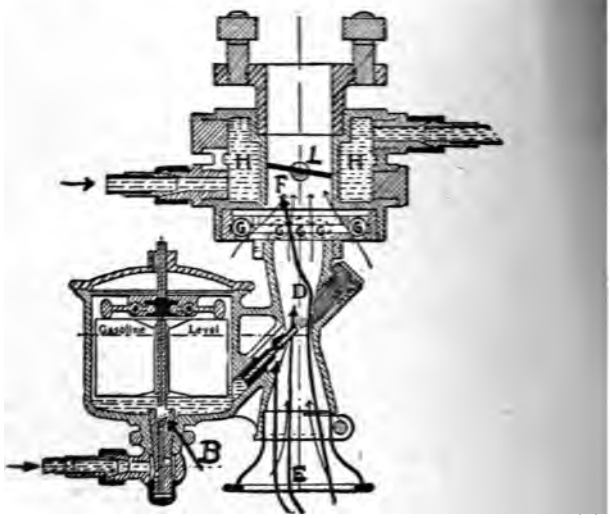


FIGURE 38.

Sectional View of Figures 37 and 39.

central in the air tube D where its area is contracted. The air for evaporation flows upward through a gauze screen in the large opening E at the bottom. The contraction of area at the bottom middle of the air tube peculiar, but there is a scientific reason for its tube formed in this way, shown enlarged in Fig

is called a venturi tube from the name of its Italian inventor. The amount of air or any gas flowing through a short tube can be greatly increased or the amount modified by the form of the tube. Strange to say, the greatest flow is not obtained by using a straight tube, as at A, Figure 40. On the contrary, more air will be delivered by the contracted tube shown at B, where the

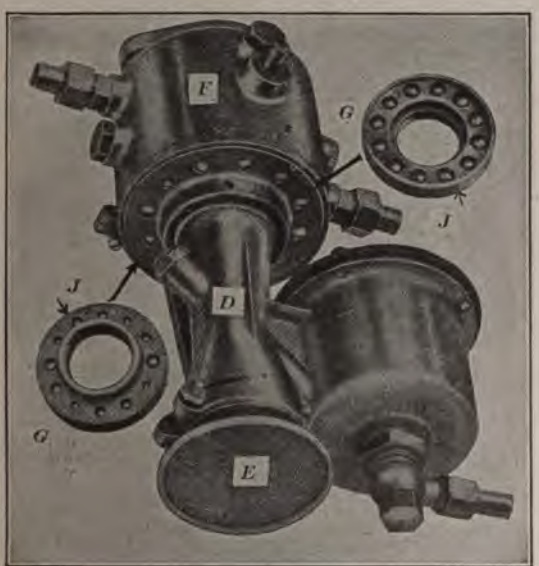


FIGURE 39.

The Auxiliary Air Valve Consists of a Row of Bronze Balls of Different Weights.

outlet from the reservoir tapers thirty degrees and the delivery end of the tube has a seven-degree taper. This greatly increased flow of air around the spray nozzle aids in the evaporation of the oil, and the vapor is de-

livered in an expanding volume in the mixing chamber where the additional air is admitted.

The auxiliary air valve on this carbureter is distinctive. It consists of a row of bronze balls G, Figures 38 and 39, set in a cage J, each ball covering an air inlet. The balls are graded in weight, so that as the suction of the engine becomes greater from the increased speed, the lightest ball will be lifted from its seat first and ad-

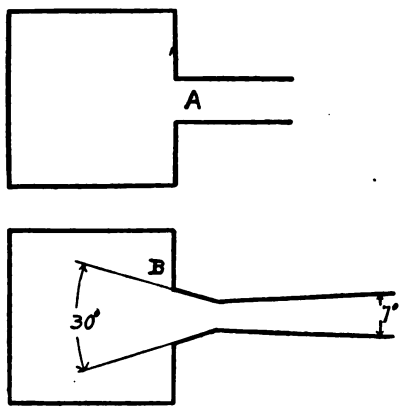


FIGURE 40.

"The Amount of Air or Gas Flowing Through a Short Tube can be Greatly Increased or the Amount Modified by the Form of the Tube."

mit more air to the mixing chamber F. Following the lifting of the lightest ball, the others are lifted in the order of their weights with the further increase of suction until the entire auxiliary air supply becomes available at the maximum speed of the engine. The carbureter size is selected for the power of the engine and its service, and its operation is entirely automatic aside

from the handling of the throttle valve L. The throttle is operated by means of a small lever mounted on the steering wheel of the auto. A system of rods and levers connects the hand lever to the throttle, the rod M and the lever N, Figure 37 being a part of this system. Two adjustable screw stops O, Figure 37, are set so as to strike the nut P and limit the throw of the throttle valve. The hot water jacket H around the vaporizing chamber is connected to the engine jacket. The extra heat is quite necessary, especially in the winter season and for using the heavier grades of gasoline now on the market.

Cotton Double-Tube Carbureter.—It is well known that fifty per cent of the troubles causing "shut downs" in gas engines is due to faulty ignition; not to that part which furnishes the electric current supply, but to that part on the engine which engages the compressed charge.

In large gas engines having a plurality of cylinders a defective igniter is replaced by cutting out the cylinder, extracting the igniter and inserting a new one, while the engine is running. Such a method is very amateurish and dangerous as the gas continues to flow in and out of the igniter canal with intense force, and the power of the engine is very much lowered.

Figure 40A illustrates an igniter which it is claimed eliminates most of the trouble with this, the most vital point in the machine. The device consists of a casing, preferably water-jacketed, containing a pair of ignition pockets in which are located the electrodes. A central hand-controlled valve, having a passage leading to the combustion chamber, opens or closes communication between the combustion chamber to either of the ignition pockets. The electric circuit is connected to a binding

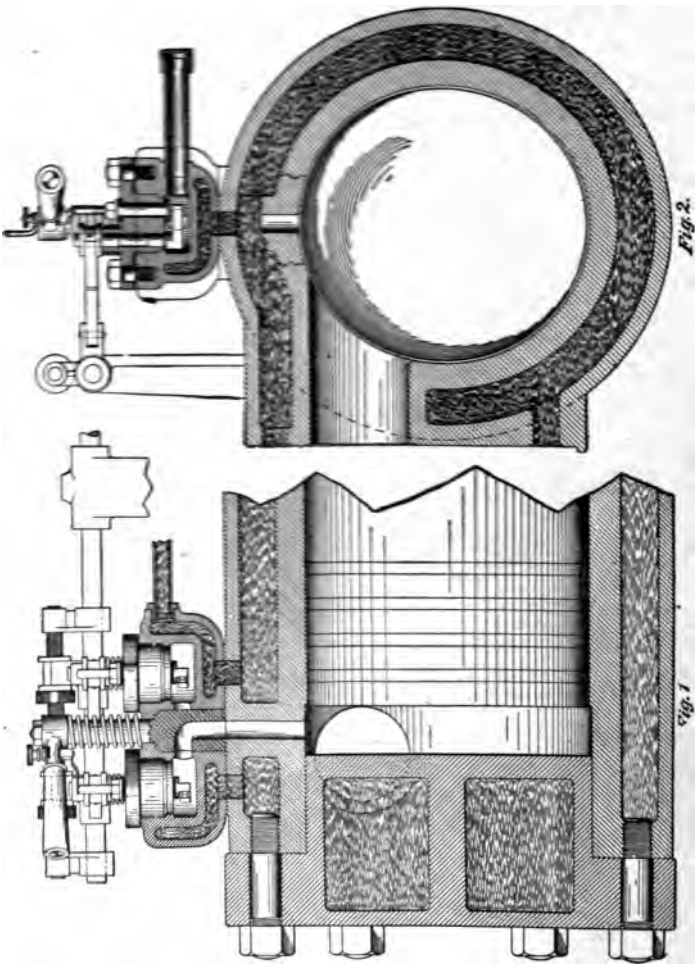


FIGURE 40A.
Cotton Carbureter.

post located on and insulated from the valve-handle and closes the circuit with the insulated electrode located in the pocket which has been set in communication with the combustion chamber.

The tubes extending from the pockets shown in Figure 40A serve to receive any incombustible gas that may have been retained in the pockets after exhaust.

It will readily be understood that a defective plug can be cut out and a new one set in operation almost instantaneously while the engine is running and the defective one taken out and repaired.

In this device ignition first takes place in a pocket which causes an intense blast of flames to pass through the combustion chamber resulting in the bulk of the gases being broken up very quickly and a resulting rapid raise of the combustion line and consequently higher M. E. P. Jump spark, magnetic arc, or make-and-break systems may be used therewith.

Adjustment of the Carbureter.—On some carbureters there is no gasoline adjustment and one or two for the air; on others there is one or more for the gasoline and possibly two for the air. The first step in the adjustment is to see that the gasoline is properly fed and the action of the float and its valve are corrected, after which the needle points may be opened (if of the adjustable needle point type) to some point that might suggest itself as being near enough to get the engine started. If the carbureter is of the fixed spray nozzle type the air valves should be adjusted to some point that might suggest itself for starting. To overcome this defective adjustment it is a good plan to prime the engine through its priming cup, or at the carbureter by means of the primer, found on most carbureters. It will generally be

found that the engine will start readily, after which one can in a very short time adjust the carbureter to a position that the engine will continue running.

Adjusting the engine for slow running without load should be done by closing the throttle valve and retarding the spark which is the slow operating position for all engines. The carbureter now can be very easily adjusted to the best efficiency for this throttled condition by increasing or decreasing the fuel supply by the various methods found in different carbureters. Keep changing the adjustment of the fuel until the position is found where the engine seemingly has the best efficiency, and the air valve or valves are free from action, or in other words all the air passing into the carbureter should pass through the fixed air inlet. By so doing, the air valve adjustments are reserved for higher speed running. This condition gives the carbureter a greater range in its action, thus adding to the flexibility and power of the engine.

Next test the engine for higher speed without load to ascertain if the carbureter is adjusted for speed. Leaving the spark in its retarded position open the throttle and note the action of the engine. If the engine seems to choke or fill with gas it is an indication that the gas is too rich and should be rectified by admitting more air through the air valve. This adjustment is accomplished by reducing the spring tension on the air valve thus giving it a freer action which increases the area of the opening, allowing more air to enter.

In case of a carbureter with a mechanically operated needle point, which operates in unison with the throttle, this choking condition can be overcome by reducing its action, thus cutting off the supply of gasoline when the

throttle is opened. The other extreme when opening the throttle should be too lean a mixture or the lack of gasoline. This condition would indicate itself by back-firing or snapping at the mouth of the carbureter. Adjustments to overcome this condition are obtained by simply reversing the aforesaid methods of adjustments for too rich a mixture. If the back-firing is not serious it is possible to overcome it by advancing the spark and again opening the throttle, which shows that the carbureter is near its correct adjustment.

The best guidance while adjusting carbureters is to keep them adjusted as close to a back-firing condition as possible.

If after the adjustments are all made, and an occasional back-fire is present at all speeds, it indicates that the carbureter is properly adjusted throughout its range, and the back-firing condition can be overcome by the addition of a trifle more gasoline, which will affect the mixture at any position of the throttle.

In a carbureter with no needle valve or gasoline adjustment there is always a slow speed air adjustment and one or more adjustments for high speeds. In this case see that no air can enter through the high speed inlet on low speed, then adjust this low speed until the motor runs smoothly and evenly. When the low speed adjustment is correct open the throttle a little and adjust the second air intake until the engine runs properly; then the third, if there is one. The air should be adjusted so that the engine will neither choke nor back-fire when the throttle is opened suddenly.

In the case of a carbureter having two or more needle valves, the method of procedure for adjusting is practically the same as that just described. All that is nec-

essary to do is to adjust the slow speed needle valve and the slow speed air. When the engine works all right at slow speed the throttle should be opened a little wider, when the second needle valve and the second air intake may be adjusted.

CHAPTER XI.

MODERN IGNITION.

Of all the ills to which the gas engine falls heir, it is safe to say that more of them can be laid to ignition trouble than any other cause. This trouble is not all from poor ignition outfits, as a large percentage of it can be laid to the incompetency of the engine operator.

The field for the use of gasoline engines has developed so widely that the engines are being handled now, in a great many instances, by men whose interests lie in other directions and who have not the time and opportunity to make a special study of the engine and its accessories. Engines are so constructed throughout that the only necessary attention is an occasional oiling, and some attention to the ignition system. The ignition system is now the only part of the equipment that is sure to need some attention at times. This is due to the fact that batteries are used as a source of current and since the battery energy finally becomes exhausted, renewals have to be made.

When the battery becomes weak, it is customary to adjust the spark coil to compensate for the lower voltage and this means that when a new battery is installed, unless the adjustment is lightened again, the coil is drawing too much current. This runs the battery down more rapidly than is necessary and causes burning of the contact points on the coil.

Auburn Spark Plug.—The Auburn ignition spark plug No. 1, see Figure 41, is a mica plug only and made in

FIGURE 41.

FIGURE 42.

all sizes, while Auburn ignition spark plug No. 2, Figure 42, is made in porcelain or mica. These plugs represent the highest art of spark plug manufacture and are guaranteed in every particular.

An illustration, Figure 43, is also shown of the Auburn ignition timer which is made for one, two, three or four-cylinder engines. The contact and roller of this timer are made of high grade, imported non-magnetic steel. It has self-lubricating bearings and is guaranteed not to heat.

Ignition Mechanism.—A form of ignition mechanism used in connection with the primary make and break system of electrical ignition is illustrated in Figure 44. Upon the operating rod being moved to the left, the pawl, carried by the upper arm of the bell-crank lever, forces

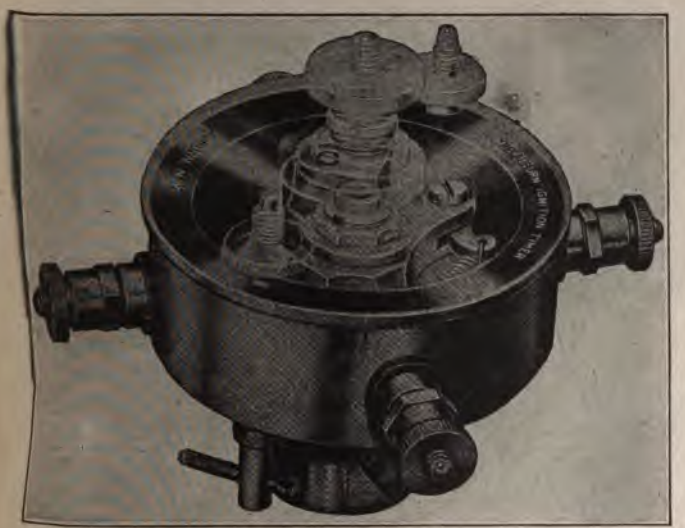


FIGURE 43.

downward the small trigger carried upon the outer end of the movable electrode and in this manner passes by it. Upon the return stroke of the operating rod the upper end of the pawl engages with the trigger, bringing the contact-points of the movable and fixed electrode together for a short period of time. A further movement of the operating rod in the same direction causes the trigger to be released from contact with the pawl. This action causes the contact-points of the electrodes to suddenly

fly apart and a spark or arc is produced between them.

Reason for Advancing Point of Ignition.—It may be well to explain, without entering into theoretical details, that when an engine is running at normal speed the ignition mechanism is so set that ignition takes place slightly

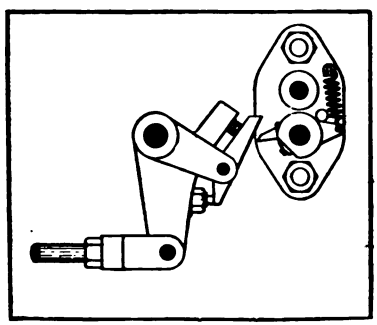


FIGURE 44.
Ignition Mechanism for Use in Connection with a Primary Make and Break Spark.

before the piston reaches the end of its compression stroke.

If the charge is fired at or after the end of the compression stroke, the average pressure on the piston, and consequently the power, is decreased in proportion. Therefore to ensure perfect combustion with a maximum pressure at the commencement of the explosion stroke, the point of ignition must be earlier, and advance as the speed increases.

Spark Coils and Magnetos.—The Pfanstiehl coil, shown in Figure 45, is so constructed as to eliminate any chance of battery or coil trouble in the hands of inexperienced users. This feature is principally due to the vibrator, the tension of which is controlled by a sep-

arate coil spring, which has a limited movement so that the tension cannot exceed an amount necessary to produce a good spark for a high compression engine. It is impossible to make these coils draw more than three-fourths of an ampere on a dead short circuit, with the vibrator working; and on the timer of an ordinary engine, they will draw from 0.1 to 0.25 of an ampere. This means that the maximum service will always be obtained from the dry cells and that the points will not burn excessively.

FIGURE 45.

The contact points are composed of the highest quality of platinum iridium alloy that it is practicable to work and this high quality, combined with the fact that the points are never changed in their relation to each other by adjustment, insures a minimum of trouble from this cause. The Pfanstiehl coils are further characterized by the patented method of winding, by which the secondary is made up of pancake sections, and these sections are assembled over the primary and core. This method of

[illegible] necessary in large coils for X-Ray [illegible] as it insures perfect insulation and [illegible] the efficiency of the coil. It has not been used on [illegible] coils until within recent years on account of the expense involved, but due to the Pfanstiehl special method of construction, this winding can be used without adding materially to the cost of the coil.

[illegible] magneto for [illegible] of trouble [illegible] This magneto [illegible] should be [illegible] There are [illegible] [illegible]

magnetic iron, perfectly balanced, so that the magneto will run at practically any speed without injury. The coil is self-contained and furnished with the magneto. This insures the perfect working of the entire sytem and greatly simplifies the wiring. As may be seen from the illustration, the coil is placed under the arch of the magnets and securely fastened and only three wires are used in the whole wiring system, one to the spark plug, one to the ground and one to the timer. This magneto will start any engine that can be turned over by hand and the use of batteries is entirely eliminated. No changes in the engine are necessary as it is used in connection with the timer already on the engine. The magneto works just as well in cold or rainy weather as it does in warm weather and thereby insures starting under all conditions.

The bearings are very large and the oiling arrangement is positive and will operate under all conditions. As an extra precaution, terminals are placed on the coil so that batteries may be used with it in case of emergencies, or for starting very large engines that cannot be turned over by hand. The vibrator on the coil of this magneto is covered by a metal cap, which can be removed in case an adjustment is necessary. This adjustment will only be necessary, however, on an engine where the conditions are very unusual and when once made is permanent.

Timing the Magneto.—The accurate timing of a magneto is an important factor in the efficient operation of gas engines, and must be studied with considerable care.

No cut and dried rule can be established for timing, inasmuch as the ignition point varies according to peculiarities and characteristics of the individual engine.

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It has been stated that the correct point of ignition is ⅛ of the engine stroke; thus, for an engine of 5-in. stroke, the ignition advance should be ⅝ in. before top dead center.

It is quite true that some engines of 5-in. stroke require an advance of ⅝ in., but it is equally true that with other 5-in. stroke engines an advance of ⅝ in. would be quite incorrect.

If an engine is so constructed that the combustion space is compact, the required advance would be considerably less than the proper advance for an engine in which the combustion space is considerably extended.

The normal speed of the engine is one of the great factors in establishing the ignition point, for it goes without saying that a far greater advance is required for an engine running at 1,200 r.p.m. than for an engine running at 600.

Another factor that must be considered is the stroke of the engine, for the longer the stroke the greater must be the advance, other conditions being equal. Thus, an engine of 5-in. bore and 7-in. stroke will require a greater ignition advance than an engine of 5-in. bore and only 5-in. stroke.

Another consideration will be the location of the spark plug. If this is located in the center of the combustion space, and with its point projecting into the mixture, a small advance will be required, whereas if the plug is located on one side of the combustion space and is possibly pocketed, the advance required will be far greater.

The exact advance for maximum efficiency can only be determined by experiment.

In timing a magneto of the usual rotating armature type, fair all-around results may be obtained by so set-

ting it that in the full retard position it gives its spark at the instant when the piston is at top dead center. Whether or not the advance position will be found correct can only be determined by trial, and if it is found not to be so the relation of the armature to the crankshaft can be altered in accordance with carefully noted tests until the results are satisfactory.

Another statement that is made is that if a user of an engine desires to have it throttled down to a very low speed, the spark plug points should be opened up until they are fully 1/16 in. apart.

This statement is exactly contrary to the actual conditions. When a magneto runs at slow speed, as will be the case when the engine is throttled down, it does not produce a current of as high a voltage as will be the case when it operates at increased speed, and in consequence the current will not be able to jump across as wide a spark gap. Thus if it is desired to throttle an engine down low, the spark plug gap must be much smaller than is required for higher speeds. For high tension magneto ignition 1/50 in. spark gap will give correct results for all normal operating speeds. Engine characteristics have some influence on the size of the spark gap, but in no case should this gap be greater than 1/32 in.

Delco Ignition System.—The Dayton Engineering Laboratories Company, of Dayton, Ohio, have placed on the market a novel battery ignition system. In order to simplify the wiring, the different parts are combined into a compact unit, of the same outward appearance as a coil box, with a throw-over switch on the outside of the box. This arrangement, known as Model 1, is designed to be secured to the dash in place of the regular coil.

[illegible] from No. 1 in [illegible] mounted on the da[illegible] [illegible] for each e[illegible] [illegible] and a circuit bre[illegible] [illegible] mounted on the m[illegible]

[illegible] breaker and high [illegible] The distrib[illegible] [illegible] metal housing [illegible] connection, the d[illegible] [illegible] The housing [illegible] as to be readi[illegible] [illegible] shaft is mount[illegible] [illegible] centers of whic[illegible] [illegible] adjusting, the dis[illegible] [illegible] removed, the hea[illegible]

[illegible] arm A, which is [illegible] the coil spring B [illegible] arm is made up [illegible] which is mounted the [illegible] and the con[illegible] [illegible] initial tension [illegible] of the steel [illegible] platinum contact [illegible] similar point at G on the [illegible] the two points is such [illegible] arm has moved about [illegible] tension in the contact [illegible] at the contact points. The movement [illegible] arm is limited by a stop I to [illegible] by the coil s[illegible] [illegible] This spring is very light and is fastened to th[illegible]

close to its pivot. The short movement of the spring allows very high speeds on account of the absence of

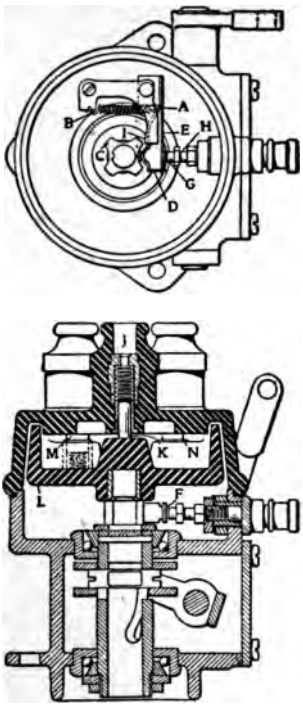


FIGURE 47.

inertia. The four-lobed cam is so formed as to impart the full movement to the arm in a small fraction of one revolution, thus avoiding any serious lag in moving parts, or variation due to adjustment.

In the high tension distributor, the current from the coil in introduced at the central terminal J, which pro-

jects into the chamber as shown at K. Upon the disc L is mounted a steel brush M, which is connected to the center terminal by a bar N. In operation the brush, being normally held against the head by a light spring, makes contact with the outer terminals successively and at the instant the contacts are closed in the primary circuit. It is claimed that there is little arcing in the distributor, and the pressure upon the terminals is very light, so that the wear on the brush is reduced to the minimum. The flange on the disc projecting into the grove in the distributor head effectively insulates the terminals from the housing and other points to which the spark might jump.

The spark control is effected by means of a spiral slot in the distributor sleeve, upon which the four-lobed cam is rigidly mounted. A bronze ring, which is slidably mounted upon the sleeve, carries a pin which passes through the spiral slots. A forked yoke, carrying two pins which co-act with the groove in the ring is rigidly mounted upon a shaft, to which the timer lever is connected. The rocking of the yoke by means of the timer lever causes the ring to slide along the sleeves, the spiral slots in the sleeve causing it to rotate, thus changing the relation between the four-lobed cam and the engine shaft as desired.

Battery Ignition—Dry Batteries.—A dry cell battery is a chemical and mechanical combination, and a power unit within itself, and consequently has certain limits to its capacity to generate current. Chemicals are always a rather delicate proposition to handle, and to give best service it is unnecessary to say that dry cells should first be properly constructed, with proper proportion of chemical ingredients used.

The outer cup is made of zinc, and acts as the positive electrode. Over it is slipped a strawboard tube. The object is to prevent the zinc of two cells from touching each other so as to establish a wrong connection. The negative electrode is a plate of carbon. This is placed in the center of the zinc, and is so supported as not to touch it in any place. Carbon and zinc both carry binding posts. The filling varies. The following is used in the Burnley cell:

A wooden plunger or template, somewhat larger than the carbon, is inserted, and the following mixture introduced: Ammonium chloride, zinc chloride, 1 part of each, plaster of Paris, 3 parts, flour 0.87 parts, water 2 parts. After this has set a little the wooden template is withdrawn, the carbon is inserted in the cavity left by its withdrawal, and the space left unfilled is filled with the following mixture: Ammonium chloride, zinc chloride, manganese binoxide, granulated carbon, flour, 1 part of each, plaster 3 parts, water 2 parts. The electromotive force of this cell is 1.4 volts, its resistance 0.3 ohm.

The Gassner dry cell has as negative element a cylinder made of a mixture of carbon and manganese dioxide. The filling composition is as follows: Zinc oxide, ammonium chloride, and zinc chloride, 1 part each, plaster of Paris 3 parts, water 2 parts.

For the Meserole dry battery, there are mixed the following: Graphite, slacked lime, arsenious acid, and glucose or dextrine, 1 part each, carbon and manganese binoxide, 3 parts each. The mixture is finely pulverized and rubbed up in a saturated solution of ammonium chloride and sodium chloride (common salt) with one-tenth its volume of a solution of mercury chloride and an equal volume of hydrochloric acid. These constitu-

ents are intimately mixed and poured into the zinc cup.

Dry batteries are sealed with pitch. A hole is sometimes left for the escape of gas.

Placing Cells.—Great care should be exercised when placing dry cells into the battery box. A good method is to proceed as follows: Take each cell and roll it up, cardboard and all, in a long strip of heavy manila wrapping paper, so that it is covered with about half a dozen thicknesses. The paper can be held in place by a few wrappings of insulating tape. Cut the paper about an inch or so longer at either end than the full length of the cell, so that the ends of the paper wrapper can be turned in. Before doing the latter, however, the cells should be connected and each terminal wrapped with a few layers of insulating tape. The connecting wires should be at least No. 14 gauge, rubber covered, and when they are subject to excessive jarring, flexible wire with lock nuts on the cells should be used. Wiring should be installed with knobs and cleats, such as are used in electric light installation, and the wires should not come in contact with any surface except its supports.

The various methods of connecting dry cells for gas engine ignition are explained under the heading "Battery Output," and plainly illustrated by Figures 50 to 53.

Arrangement of Cells.—The usual way to arrange a number of cells to form a battery for ignition purposes, is what is called a series, that is, the zinc from one cell is connected to the carbon of the next one and so on. One cell is arranged directly behind the other in this arrangement and the current is compelled to pass through all of the cells.

Another method of arranging cells in a battery is to connect all of the zincs together and all of the carbons

together. This amounts to the same thing as making one large cell having a zinc as large as the sum of all the zincs and a carbon plate whose area is equal to the sum of all the carbons. This method of connecting is called connecting in parallel.

When not in use, and also if possible when in use, dry cells should be kept in a cool dry place, away from excessive dust and dirt, and during the term of hot summer months care should be taken that the sun does not shine directly on them, for the reason that, owing to the peculiarity of the chemicals, they become exceedingly active at high temperature, and under such conditions occasionally moisture will appear around the tops, thus short-circuiting the whole set. Water, oil drippings and wet cases should be carefully avoided.

Most, if not all, of the dissatisfaction with dry batteries for ignition work has arisen not because of any inherent defect in the battery, but because of the unfortunate selection of a battery entirely inadequate for the duty forced upon it. If we insert a low reading ampere meter in the battery circuit of a gas engine while in operation, a current flow of .3-.5 ampere will be indicated. This does not represent the actual demand made on the battery; this current drain is actually a series of discharges from the battery, averaging about 4 amperes each. Therefore, when a battery reaches a point when it will no longer force this amount of current (about 4 amperes) through the coil it should be replaced by a new one.

Storage Batteries.—The ordinary 6-volt, 60 ampere-hour storage battery is composed of three individual cells, the elements of which are connected up in series. Each cell usually consists of a hard-rubber jar, containing one

negative element and two positive elements, which are formed of lead, and honey-combed, or cast in a "grid" form, and the openings filled with the active material, consisting of a paste, formed of a mixture of oxide of lead (red-lead) for the negative elements and litherage (yellow-lead) for the positive elements mixed with dilute sulphuric acid. The elements are separated and prevented from touching each other, within the cell, by a perforated sheet of hard-rubber, or other means, allowing of a free circulation of the electrolyte.

The electrolyte is made up of a ten per cent solution of sulphuric acid (chemically pure) and distilled water, or clean filtered rain water. The acid should be poured in a fine stream into the water, when making up the solution, and slowly stirred with a glass rod or clean wood stick, until the density or specific gravity has reached 1.21 or 1.215. The solution heats rapidly upon adding the acid, and hydrometer reading should not be taken till the solution cools. Great care should be exercised in adding the acid to the water to prevent slopping—never pour the water into the acid—and never place the solution in the cells while hot.

The density of the electrolyte in a fully charged cell should never be over 1.28 to 1.3, and when reduction of the density is necessary, the water should be added a little at a time, and the solution thoroughly agitated so as to get a uniform density throughout the solution. Always correct the density after the battery has been fully charged, using a standard storage battery hydrometer for these tests. For the portable types of storage batteries, a small twenty-five cent syringe with rubber bulb and hard-rubber nozzle is a cheap and handy instrument with which to draw the solution out of the small vent, or filler

openings, and also to force water into and agitate the solution.

Even if standard electrolyte is furnished with the battery, it becomes necessary in time to reduce or build up the density, so as to keep it in the most efficient condition. A new storage battery, especially of the portable type, will stand a great deal of abuse without showing any immediate apparent loss of efficiency, but abuse, with this as with anything else, eventually means ruin.

Usually the details of testing the solution, or electrolyte, as it is termed, is left to the person who does the recharging and who, frequently, is inexperienced and incompetent to intelligently perform the task. If the battery were taken to a recharging station where a specialty of this work is made, less trouble would be experienced. However, more frequently, the owner does not have access to such facilities, especially in the rural districts, and must depend upon the local, or nearby electric lighting plant for this service.

As some forms of storage battery ignition systems are equipped with a low voltage direct current dynamo or magneto, which is connected to the battery so as to keep it in a fully charged condition, the owner does not have to contend with the incompetency or carelessness of outsiders; however, instances are encountered in cases of this kind where the electrolyte had been permitted to evaporate almost entirely, thus rendering the battery useless. Whatever form or type of storage battery is used, the plates, or elements should always be kept immersed in the solution, preventing exposure of the plates to the air, for when the plates are exposed they not only sulphate rapidly, but the decreased area of plate surface exposed to the chemical action of the solution, reduces

the capacity of the battery, while a sulphated condition has a similar effect.

Charging Storage Batteries.—Instructions, relative to charging and care, are invariably furnished the purchaser of a storage battery and should be closely followed by the user.

When the battery has been discharged, the density decreases, owing to the absorption of the sulphuric acid by the plates or elements, and when fully charged, or being charged, the density increases, because of the reversal of this operation—that is, the acid is thrown back into the solution, and this variation is directly proportional to the ampere-hour charge or discharge, between certain limits.

The charging rate, or the number of amperes passed through a cell in the process of charging, should never exceed that rate stated in the instructions, and usually stamped on the name-plate. This rate ordinarily is from 5 to 6 amperes for a 60 amp.hr. battery, and 3 to 4 amperes for a 40 amp.hr. battery. Hence it would require 12 hours to fully charge a 60 amp.hr. cell at a 5 ampere rate, or 10 hours at a 6 ampere rate and so on. If this rate is exceeded slightly, say 1 or 2 amperes, it should be but for a short period, as continued overcharging is injurious as well as wasteful.

An exhausted cell, charged at a normal rate for five minutes, will show a normal voltage, but it will be incapable of yielding a normal current, and the current is the vital agent. The voltage of a healthy storage cell should be from 2.02 to 2.10 volts when fully charged, and from 1.98 to 2.00 volts when discharged to a safe limit. Excessive discharging will result in the same trouble as excessive charging, and eventually ruin the

The caps, used in covering the filler openings, should be removed when charging, and replaced when discharging to exclude all dust and dirt. No metallic or conducting element should ever be inserted in these openings.

Capacity.—The capacity of a storage battery expressed as 40 or 60 amp.hr. means literally the ability of that battery, when fully charged, and in normal condition, to deliver approximately one ampere for forty or sixty hours, as the case may be, but does not imply that a current of forty or sixty amperes may be discharged for one hour. The lower the rate of discharge, the greater the length of time the battery will hold up, and the greater the discharge, necessarily the shorter its life.

Testing.—The practice of testing a storage battery to determine whether or not it is charged, by momentarily completely short-circuiting its terminals to observe the spark, is, to say the least, misleading. A cell may be so nearly exhausted that its voltage would not force enough current through the resistance of an ignition circuit to "spark" an engine, and yet, if its terminals were short-circuited momentarily, a vigorous spark would result. The practice is injurious to the battery, and it does not have a fair show with this kind of treatment.

An increase of from 30 to 50 degrees in the density, with a corresponding rise in voltage, of say ten to fourteen hundredths of a volt, denotes a charged condition, while a decrease of these values proportionately denotes a discharged condition. Care should be exercised in recharging, to see that the positive wire from the source of supply is connected to the positive terminal of the battery, and the negative wire to the negative

terminal. Any other connection will result in the battery receiving its charge in the reverse direction and cause trouble. It is of no consequence, however, which terminal is grounded, and which connected to battery side of coil in an ignition circuit, though it is good practice to change polarity occasionally, as this will cause a more even wear of the platinum contact points, in either the make and break, or vibrator coil.

If for any reason the battery is to lie idle for any length of time, it should be fully charged, then the solution should be withdrawn and the jars filled with distilled water, so as to cover the elements completely, and the battery set away, free from grease and dirt. Never allow the battery to remain idle and uncharged.

Reference has already been made to the specific gravity or weight of the electrolyte as compared to that of water. The specific gravity is tested by means of an instrument called a hydrometer.

At the end of the complete discharge the specific gravity will read somewhere about 1.15. If only half discharged, then about 1.20. If only one-quarter, 1.125, or three-quarters, 1.175, so that one may arrange a scale whereby the amount of charge used, or that remaining in the cells, may be estimated.

On re-charging, the specific gravity will rise from its reading of 1.15 or whatever it may be, to that of 1.25 again, thereby indicating the cell has received its full charge. In cases where the specific gravity will not show any rise during or at the end of its charge, it indicates a short circuit, and the cell has not received its charge. In cases where the specific gravity comes up to 1.25 at the end of its charge, but falls to a lower figure during a period of idleness or standing for sa-

24 or 48 hours, also indicates a short circuit, or else local action (or internal discharge), due to contamination of the electrolyte by some impurity.

The plates should always be kept covered with their electrolyte, or acid, because if they are exposed or out of the liquid, a sulphation occurs of such a nature as to damage the plates irreparably, besides which the exposed surfaces are inactive and useless.

Sulphuric acid should never be added to the cells to compensate loss, unless such loss has been caused by a spilling of the acid, and then first ascertain the specific gravity of the acid remaining in the cells and make up with diluted acid of the corresponding specific gravity till the plates are again covered. In all cases of adding to, or compensating evaporation losses (except as above stated) nothing should be used but pure distilled water, and absolutely pure and clean acid. A healthy battery used continuously, should not require an addition of acid more than once a week.

It is bad practice to put a wire across the positive and negative terminals for the purpose of testing to see if there is a spark. It is almost a dead short circuit and is very detrimental to the cell owing to the heavy current passing, even though it be for only a few seconds of time. In order to ascertain the strength of current it is best to use a small pocket voltmeter, reading from 0 to 3 volts.

Fluid Batteries.—Although the fluid primary cell is very useful in stationary work, it cannot very well be used on traction engines, owing to the liability of the liquid electrolyte to spill or slop over. It can, however, be utilized for charging small storage batteries that are used for ignition purposes on traction engines in lo-

calities where there is no incandescent light circuit at hand, or if the only current available is of the alternating type. The voltage of a fluid battery to be used for charging a storage battery should exceed the voltage of the storage battery by at least 30 per cent. Primary batteries of the open circuit type, such as salammoniac cells are useless for charging purposes. Only batteries of the closed circuit or constant current type are suitable.

A simple and inexpensive form of closed circuit battery for charging purposes is the single liquid type, in which zinc and carbon electrodes are immersed in a 20 per cent solution of sulphuric acid and water with nitrate of soda as the depolarizing agent. For charging a 4-volt storage battery four such cells are required, while for a 6-volt storage battery six cells will be necessary for a proper charge. This form of fluid battery has a voltage of 1.75 volts per cell.

The articles necessary for a complete charging outfit are as follows: One small pocket ammeter reading up to 5 amperes, one two-point switch, one resistance coil or rheostat (home-made), one set of closed-circuit type of primary batteries and about 25 ft. of No. 16 B. & S. Gauge, Okonite or Kerite stranded copper wire for the connections.

The method of connecting the primary batteries, resistance coil (rheostat), ammeter and swicth is plainly shown in Figure 48. The positive pole of the primary battery should always be connected with the positive pole of the storage battery, the carbon element is always the positive electrode in both dry and primary forms of batteries. If the polarity of the terminals of the storage battery are not indicated on the case by

the + and — signs, which represent positive and negative respectively, their polarity may be readily ascertained by means of a piece of moistened litmus paper (paper soaked in a solution of iodide of starch.) Place the piece of moistened litmus paper on a board or other non-conducting material and bring the wires from the storage battery terminals into contact with opposite ends of the paper for a few seconds. One end of the paper will turn red, this will be the end next to the wire connected with the negative pole of the storage battery.

The resistance coil or rheostat may be made very easily as follows: Take a piece of hard wood, 3 ins. sq. and 15 ins. long, and turn down about 13½ ins. of its length to a diameter of 2½ ins. as shown in Figure 48. Upon this turned portion cut with a round-nose tool a groove or thread one-sixteenth of an inch deep with 8 threads to the inch.

In this groove wind about 50 ft. of No. 16 B. & S. gauge bare soft iron wire, and connect with a bar and sliding contact as shown in Figure 48. To charge the storage battery, move the sliding contact to the right until all the resistance is in use, then move the switch finger to the point on the left and adjust the sliding contact by moving it to the left until the ammeter shows 3 amperes. Moving the switch finger to the right will put the battery in the circuit for charging, and the sliding contact should again be adjusted until the ammeter shows 3 amperes. The sliding contact should be adjusted from time to time to keep the charging current at 3 amperes. Should the storage battery be of 12 ampere hour capacity, it will require 4 hours' time to properly charge it, if 18 ampere hour capacity, the time required to charge it will be 6 hours. The ampere hour

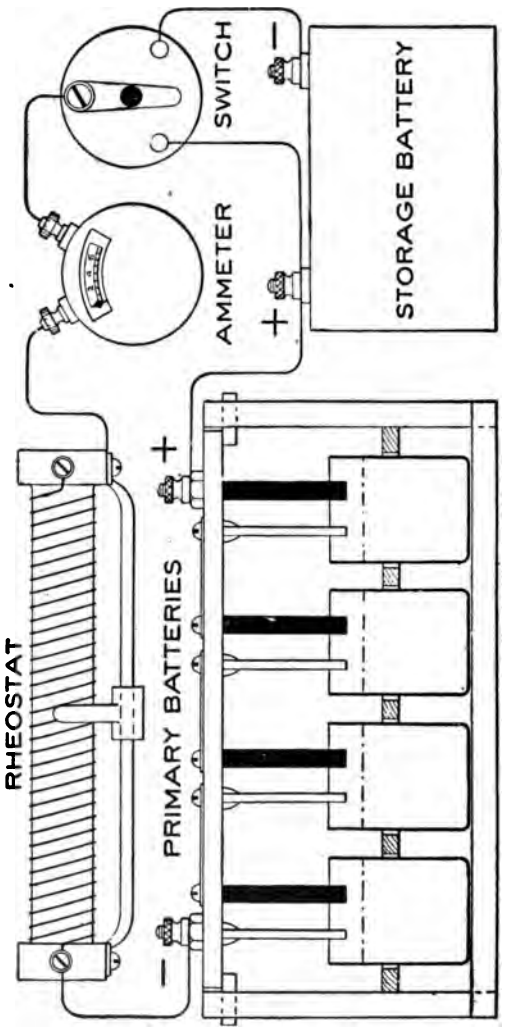
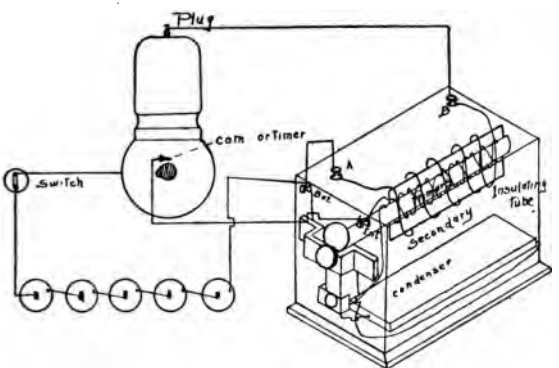

RHEOSTAT
PRIMARY BATTERIES
+
−
AMMETER
SWITCH
+
−
STORAGE BATTERY

FIGURE 48.

capacity of the storage battery, divided by the amperes of the charging current, will give the number of hours required to fully charge the battery when exhausted.

After the storage battery is fully charged the electrodes should be lifted out of the solution as shown in Figure 48, by means of the cover to which they are at-



Interior of Spark Coil.

FIGURE 49.

tached as shown, and left there until the battery is again required for use.

Box Coil Connection.—The connections on the inside of the box of an ordinary spark coil, are frequently something of a puzzle to the uninitiated, for upon opening an ordinary spark coil, all that the investigator finds is a box full of wax and if he wants to find out how it is connected up, it is necessary for him to melt out this wax, which operation commonly ruins the coil, unless he is skillful enough to replace it and replace the parts correctly. In Figure 49 everything is shown from

the engine and battery to the wiring circuit, both inside and outside the coil box, and by following these through carefully, one can get a good idea of the connections. Starting from the positive side of the battery, the current flows up to the switch into the ground connections of the engine and to the center contact of the timer; from this it goes to the insulated contact as soon as the timer turns around into position to make this connection. From here it goes to the binding posts on the front of the coil, which is usually marked "Interrupter" or "Int.' and then disappears in the interior of the box.

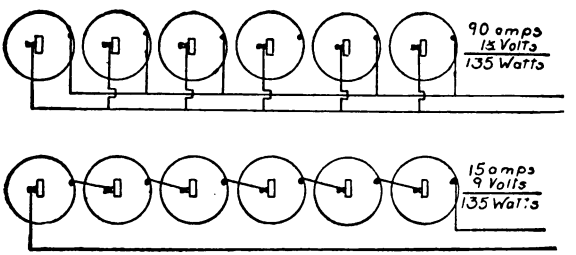
When it goes inside of the box, it either goes first to the vibrator or to the primary winding. It does not make any difference which of these it goes to first; the drawing shows it passing to the primary winding which is a coarse wire, usually of about No. 18 to No. 20 B. & S. and usually wound in two layers, though in some of the shorter and smaller coils it is wound in three. After passing through the various convolutions of the winding, it goes to the vibrator; through the contacts of the vibrator and out to the binding post which is usually marked "battery" or "bat."; from this it goes back to the battery thus completing its circuit.

Action of Electric Current.—Every electric current no matter how it is generated, must complete its circuit; that is, it must go back to its starting point. If it is not possible for it to go back to its starting point, the current does not flow, though in the case of some extremely high tension currents, such as the secondary current which is generated in the spark coil and which is shown by the smaller winding outside of the insulated tube, the current can go back through the air, but as the air

circuit has so much resistance, only a small portion can go back. The rest of the energy of the coil is dissipated or used up in forcing this small portion back. When the secondary terminals of the coil are brought close together, this current passing back through the air can be readily seen in the form of a spark and this spark is what is used for ignition purposes, but if the sparking terminals are separated by too great a distance the visible spark no longer passes and in the bright light no action can be seen, but if the coil is taken into a dark room and operated there, a thin bluish mist will be seen radiating in all directions from the exposed portions of the secondary circuit. The greatest part of this bluish light will stream toward the nearest portions of the secondary circuit which are of the opposite potential, or in other words, they will try to go back to the nearest part of the other end of the coil. In order to afford an easy path back from the end of the spark plug and avoid wiring, one end of the secondary is usually connected to one end of the primary winding. The reason for this can be easily seen by following out the wires in Figure 49. Starting from the secondary binding post A the current is generated in the secondary winding of the coil between post A and B; it passes up to the insulated portions of the plug down through it, and jumps across to the grounded side and from here it must go back to the binding post A as stated above. In order that it may go back easily, binding post A is connected to the battery binding post and through the battery binding post and connections to the metal part of the engine. The battery does not affect the secondary current in any way, so that it can pass through it easily; if however, as sometimes happens, this binding

post A is not connected to the battery binding posts and is left entirely free so that it does not connect with anything then the current has a much more difficult task before it in order to get back to the post A. Some of it will be dissipated in the air from the engine bed and frame, but more of it will pass down through the insulation inside of the coil into the primary (which, as will be seen, is only separated from this secondary winding by the insulating tube) and in this way completes for itself the circuit which should have been completed by the wire shown running from the binding post A to the battery binding post. This puts a very heavy strain upon the insulation and as the passage of a current through an insulating medium can be likened to blows of a hammer upon a piece of cast iron, it is practically only a question of time when it can break down the insulation and form an easy path for itself by burning and carbonizing the insulating material so that it can pass easily from A to the primary winding. While it is hammering its way down through the insulation, the spark at the plug will be very weak; it will probably show that there is a spark, though the plug is taken out and laid on the cylinder and tested in the air, but upon trying to run the engine the spark will be so weak that it will not give good service; in fact, it is doubtful if it will fire the mixture, although it might under favorable circumstances. As the insulation begins to break down however, the spark at the plug will begin to strengthen up and when the current has succeeded in getting down through, the spark will be fairly good, though not as good as it would be if the connections were made across from post A to the battery post, and even after a coil has broken down at one end in

this way, connecting this wire in, will materially help the spark; the coil could still be used for a connection similar to that shown in Figure 51, but would be worthless for the connections shown in Figure 52, for the reason that as soon as the spark from the binding post reached the ground through the spark plug, it would not pass into the second spark plug and back to the secondary, but would go through the ground connection and



Top, FIGURE 50.
Bottom, FIGURE 51.

back to the battery. In a great many coils this connection from binding post A to battery binding post is made inside the coil box so that binding post A is conspicuous by its absence, but it should be always borne in mind that an electric current, no matter how it is generated must go back to its starting point in order to do any useful work and the easier it can get there the more work it can do with the same amount of energy.

Battery Output.—This subject is in relation to the amount of energy that 6 cells of dry battery can give under different connections.

If each cell has 1½ volts and 15 amperes, it follows that each cell is capable of giving 22½ watts; for a watt is a volt multiplied by an ampere; thus 5 volts mul-

tiplied by 10 amperes would equal 50 watts, so $1\frac{1}{2} \times 15 = 22\frac{1}{2}$ watts, (the watt is the unit of electrical power) so that our six cells of battery are capable of exerting a force equal to $22\frac{1}{2}$ times 6 or 135 watts. This is regardless of connections or ways of grouping the cells,

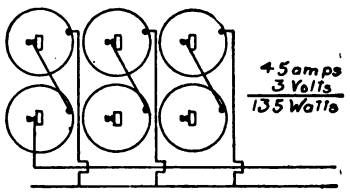


FIGURE 52.

as we can readily see by analyzing these methods of connecting these cells.

Referring to Figure 50, we have 6 cells all connected to the same pair of wires, each cell putting $1\frac{1}{2}$

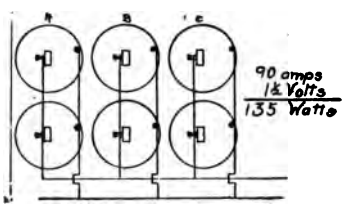


FIGURE 53.

volts and 15 amperes into the line; this is a parallel connection, so that the total amperage of the 6 cells is available, but only the voltage of one cell for the reason that each cell is connected singly to the line

and its voltage is not reinforced, nor does it reinforce the voltage of the other cells.

Perhaps this would be more clearly seen by considering each cell as a pump, capable of pumping 15 gallons of water per minute at a pressure of 1½ lbs. into a pipe line; it can be readily seen then, that the output would be that of the combined pumps and the pressure of one.

In Figure 51 the six cells are connected in series and the voltage of each one is added to the others; so that we have the combined voltage of $6 \times 1\frac{1}{2} = 9$ volts, but as the current or amperage has to pass through the resistance of all the group, the output in amperes is the same as only one cell or 15 amperes, therefore our answer is 9 volts $\times$ 15 amp. = 135 watts; our simile of the pumps will apply here as well as before.

In Figure 52 if we cover up any two groups of cells it can be readily seen that we have two cells in series in each group, and the three groups in parallel, thus giving us the voltage of the two cells in series and the amperage of the three groups, that is, each group of 2 cells gives a pressure of 3 volts and an amperage of 1 cell because as previously explained, the two are in series, so we have 3 times 15 amperes, or 45 amps. $\times$ 3 volts, which equals 135 watts.

Figure 53 is practically the same connection as Figure 50. This can be readily seen if we imagine the cells from groups B and C disconnected from the line and the terminals of C connected to B end cell and C connected to B end and as the connection is the same, the same reasoning will apply to it as to Figure 50.

As each cell can only do a certain amount of work it naturally follows that the total amount done by any

group of cells, will be the same, regardless of the way they are connected, unless some are connected so as to oppose others.

The Battery Box.—Too much care cannot be taken with the installation of batteries, for in many cases where the blame has been placed on the cells for faulty ignition and short life, the real fault has been found in the connection and the arrangement.

For the best service the batteries should be placed in a covered box for protection against dirt and moisture, and for convenience the cover should be hinged. Provide a separate box for the storage of tools and spare parts, and above all avoid laying metallic objects of any description on top of the batteries or their connections.

Connections and wiring should be arranged so that they are not disturbed by vibration nor by the opening and closing of the cover. Wires that project high enough above the cells to come into contact with the cover are in many cases the cause of mysterious misfiring, for a few slams of the cover will loosen the binding screws, and the vibration of the engine will do the rest of the mischief.

Dry batteries should always be allowed to retain their paper jackets so that there will be no danger of internal short circuits caused by the zincs of the cell coming into contact with one another. To insure the separation of the individual cells wooden partitions should be placed in the battery box, forming pigeon holes. Preferably, the partitions should be boiled in paraffine to prevent the wood from absorbing moisture.

With marine engines and portables, which are exposed to the weather, it is good practice to fill the box

with melted paraffine after the cells are in place, for the solid wax prevents the entrance of moisture and holds the cells firmly in place so that they or their connections are not affected by vibration.

Loose connections will always result from sliding loose cells, and after installing they should be fastened in place by wooden wedges driven between the cells and their partitions.

Short Circuits.—Occasionally short circuits give more trouble than a complete breakdown of the entire ignition system, because the symptoms are very much like carbureter troubles. A good and rapid way to test all parts of the ignition circuit is to run the engine in the dark, when the slightest leakage from the high tension wires or along the porcelain of the plugs will be at once seen by the faint light which indicates the short circuit. If the high tension insulation is carried out with a poor quality of rubber, or is too thin, a "short" may take place at any part. The slightest film of moisture or lubricating oil on the outer part of the porcelain plug also tends to leading away the spark and causing misfiring.

CHAPTER XII.

VAPORIZING OF FUEL.

How best to mix gasoline and air is one of the important problems which confronts the gasoline engine designer and builder and also one which gives the individual owner who is trying to improve his power plant no little concern. As the power derived from a gasoline engine depends upon the speed with which the fuel burns, and that depends to a considerable extent upon thoroughly diffusing the gasoline in the air, it is readily seen that the subject is one of vital importance.

The widely varying speeds with which gasoline may burn was aptly illustrated by a writer who said in substance that a given amount of gasoline placed in a small dish and lighted will burn in a certain length of time; if burned in a large receptacle, like the drip pan sometimes placed under a car, it will be exposed to more air and will therefore be consumed in a much shorter time. If vaporized and mixed with air in proper proportions it will burn with a sharp explosion occupying an almost immeasurably small fraction of a second.

These are familiar truths to all, but their mention will help to impress upon the mind the extreme importance of thoroughly mixing gasoline and air in order to promote rapid combustion. While proper proportioning is most desirable, complete diffusion of these proportions

must not be overlooked nor its value underestimated. Evidence of a lack of thorough mixing is indicated by the stratification sometimes shown to exist in the compressed charge by manograph cards taken from gasoline engines.

Carbureter spraying nozzles are made in considerable variety, and an impartial experimenter after carefully and repeatedly testing six of the best established forms found a considerable range in the power derived from the same motor while using the same amount of fuel, noting a variation of 19 per cent in engine efficiency between the two extremes, which can only be accounted for by the theory that some nozzles gave a more thorough mixing of fuel and air than others.

Carbureters with very small nozzles may produce a fine spray, but would appear subject to clogging with the sediment invariably found in gasoline tanks even after the most careful filtering. Instead of reducing openings through which gasoline must pass it is safer to employ some other aid to diffusion rather than use nozzles which are liable to stoppage.

Gauze in the inlet pipe has its objections, but it is a help which ought not to be neglected. It has the advantages of being efficient, without moving parts, compact, inexpensive, silent, and does not appear liable to clog.

Passing the mixture through several layers of fine gauze tends to cut it up and mix it intimately. It also provides a staggered route through which the mixture must go, and owing to the small openings and many obstructions any globules of gasoline are shattered into a state of fine division. No experience or experiments show it, but it seems as though the shape of the nozzle

would be of little consequence if the mixture is passed through several layers of fine gauze.

The gauze first experimented with consisted of three layers made of copper wire and having 110 meshes to the linear inch, with two projecting layers of 16-mesh. The fine gauze, with the large number of 12,100 openings per square inch, each less than .0056 in. square, would seem to insure a very thorough cutting up of whatever passes through it. That the inlet admitted of being obstructed by three layers of fine gauze, the opening through each of which suggested only 38 per cent of the nominal size of the pipe, must have been due to the liberal margin allowed by the designer.

Vaporizing Functions of the Carbureter.—An ideal gasoline carbureter should deliver the fuel mixture in as completely aeriform a condition, that is, as free from entrained liquid hydrocarbon, as does the mixing valve of a gas engine; but the only type of gasoline carbureter which approaches measurably near this ideal in this respect is the surface carbureter, in which the required air circulates over a very large expanse of gasoline wetted surface in the presence of an adequate available heat supply. A fuel vapor practically free from admixture of entrained liquid can be obtained from one of these vaporizers. The average carbureter of the prevailing float feed spraying type only imperfectly performs the work which it is designed to do. It occupies a position between a liquid fuel injecting device and a vaporizing device of ideal characteristics. The charge which it delivers to the intake piping consists, as a rule, of a rather weak mixture of gasoline vapor and air, in which are carried small drops of gasoline, in a condition very similar to that in which water exists in prim-

ing in steam. In the inlet piping this mixture may be modified either by a reduction of the entrained globules of gasoline and a consequent increase in richness of the aeriform portion of the charge, or less probably by a further increase in the proportion of condensed gasoline. In either case, except under very unusually favorable circumstances, some liquid gasoline reaches the cylinders, and is utilized, if at all, as is the fuel supplied by the injector system spoken of above. Its partial evaporation in the cylinder serves to enrich the aeriform portion of the charge furnished by the carbureter, but it is usually only partially volatilized, and whatever portion escapes volatilization is lost, and much worse than lost, as cylinder incrustations and an offensive exhaust result from it.

A volatile fluid, like gasoline, when it escapes in a finely subdivided and in a heated condition from a region of higher to a region of lower pressure, passes very rapidly into vapor. The extent to which the gasoline in a regular carbureter can advantageously be heated is, however, extremely limited, for if its temperature is greatly raised vaporization will take place in the passage of the jet, vapor will flow through it instead of liquid, and its capacity for passing fuel will fall to a small value and only an unworkably weak charge will result. Heating the float chamber by means of a jacket up to the safe limit materially increases the tendency toward the gasification of the fuel, especially as the gasoline when leaving the jet and entering the float chamber meets with a pressure slightly below atmosphere. The denser the fuel used the higher the temperature of the float chamber may be carried.

There is very little doubt that the supplying to the

liquid fuel directly of sufficient heat to vaporize it is a far preferable method to that of depending upon the absorption of the requisite heat by contact of the fuel with hot surfaces after entering the vaporizing chamber. It has been repeatedly pointed out that preheating of the air for the mixture is a less desirable method of supplying the necessary heat than that of heating the liquid fuel, for the specific heat of air and its conductivity are low, and the heat required for the vaporization of a fuel globule is applied externally to that globule by the warmed air.

In the case of a carbureter having a hot jacket about its vaporizing chamber there is constantly a film of gasoline adhering to and taking its heat of vaporization from the warm walls, which film is constantly being renewed by the breaking against the walls of the globules from the jet. As the liquid laden air in the vaporizing chamber is in violent motion the chances of the liquid particles meeting the warm walls are good, and the vaporizing effect is good, so far as it goes.

Heating Devices.—Heat from the circulating water only becomes available in its fullness after the motor has been run for a length of time sufficient to bring the temperature to the normal operative value. Strictly speaking, the temperature of the jacket water should increase with the instantaneous rate of fuel consumption, and in a way this is automatically brought about; but there is quite a time lag between a sudden call for increased fuel consumption and the rise in jacket water temperature which this brings about.

Heat supplied from the exhaust is fully available as soon as the motor begins to run, and the exhaust temperature varies with the rate of fuel consumption with-

out any time lag between the two. Jacketing with the exhaust has the objection, however, that water, excess lubricating oil and soot carried by the escaping gases are likely to foul and even to clog any small passages which may exist in the system.

An internal combustion engine can be operated with any good carbureter. A measured quantity of fuel can be squirted upon the inlet valve during each suction stroke or introduced into the combustion space through a special injection nozzle. This practice is common in stationary work, where low rotary speeds prevail. The valve and the port walls and other adjacent surfaces swept by the entering charge constitute the vaporizing surfaces under these circumstances, and they have the advantage over the evaporating surfaces of many carbureters of being in a constantly heated condition. During the compression period, in such an engine, high temperatures are reached on account of the high pressure carried, and vaporization is thus completed. Liquid fuel cannot burn as such, and can only unite with oxygen when in the aeriform condition. Whatever fuel remains in the liquid condition up to the beginning of exhaust is ejected unburned, and all fuel failing of vaporization up to the end of the compression stroke is very inefficiently utilized.

Adjustments.—First adjust for slow running. Set the spark back, shut off the air valve, and close the throttle slightly. Under such conditions a richer mixture will be required than for high speeds. First close the needle valve and then open it little by little until the engine runs steadily. Give it just a little more gasoline than it seems to need under these conditions. By all means have the engine driving its load while making these tests.

Next, open the throttle and advance the spark slightly. You will find then that more air is needed. Supply this by diminishing the compression of the air-valve spring. Let the engine run for some little time after each adjustment, especially if it is a two-cycle engine.

After this, advance the spark as far as it will stand; that is, until the engine begins to skip. The final adjustment may now be made, generally by admitting a little more air, and perhaps a very little more gasoline. Juggle it until you get the maximum speed. When once set, leave it alone.

In multiple cylinder engines, each cylinder may be tested out separately by shutting off the spark from the others. This will often show that some cylinders require more fuel than the others, in which case the best results will be obtained by using the average.

Gasoline Engine Backfiring.—By the word "backfiring" is meant the explosion of a charge or a part of it when the inlet valve is open and the mixture is entering the cylinder. The inlet valve being open, allows the force pressure or expansion to escape into the carbureter or mixer, or into the crankcase in a two-cycle engine. This often causes a regular shot gun report, which seems to, and actually does, come out of the open end of the inlet pipe. It has been expressed in different terms, "shooting out of the intake pipe," "exploding in the carbureter or crankcase," etc. But what is the cause of it, and how may it be overcome, are questions that all operators are interested in. It is known that oftentimes feeding a little more gasoline will overcome the trouble, but why this will do it is not generally known. In the majority of stationary and portable gasoline engines no attempt is made at keeping the air and gasoline at con-

stant proportions as is done in the automobile carbureter. In the ordinary gasoline engine, after it is started, the air volume entering the cylinder remains constant, and if the gasoline needle is set a little too close, the mixture verges on the rare point, which causes it to burn slowly and continues a flame in the cylinder quite often during the entire exhaust stroke. And even after the intake valve opens and the fresh mixture comes rushing in, there yet lingers a flame from the previous combustion, which instantly ignites the new charge as it enters the cylinder. The flame spreads through the entire mixture clear into the mixer or carbureter which, the inlet valve being open, results in a backfire. One can readily understand then how feeding more gasoline, so as to insure a rich, quick-burning mixture, which will consume itself before the end of the exhaust stroke will prevent further backfiring from this cause.

Carbon in Cylinders.—Carbon deposit in the cylinder is one of the most fruitful sources of trouble in a gasoline engine. If the cylinders get too much lubricating oil a portion of it will work up past the pistons; the intense heat will consume or evaporate the oil, leaving a deposit of carbon; this may be augmented by too rich a mixture, which serves to deposit lamp black or carbon in a film on the inside and top of the compression chamber and on the heads of the pistons. The films thus formed will in time commence to scale and, the projections becoming fused by the heat of the explosions, will serve to prematurely ignite the charge.

The symptoms are backfiring and knocking in the cylinders, as if the spark were too far advanced. An almost infallible symptom of excessive carbon deposit in the cylinders is the motor showing plenty of power at

high speed, but deficient in hill-climbing on high gear. At low engine speeds the incandescent carbon projections serve to pre-ignite the charge, thereby reducing the power of the motor. The cure is to take off the cylinders and scrape off the carbon deposit, being careful not to scratch the cylinder walls. The preventative is to so regulate the oil feed as to give the cylinders enough, but not too much, oil.

Carbon will also form on the porcelain portion of the spark plugs, thereby furnishing a circuit, which the high tension current may travel over, rather than jump between the sparking points of the plug. Usually only a part of the current will pass by way of the carbon film, still leaving a weak spark at the points. This causes intermittent firing.

CHAPTER XIII.

COOLING SYSTEMS.

The function of the water jacket—or of any other device for cooling the cylinder—is to prevent the heat of the metal from rising to such a degree as to impair the lubrication, and also to prevent pre-ignition of the charge. If the metal is cooled too much a portion of the heat of combustion is wasted by being uselessly conducted away. In a water cooled cylinder the temperature of the water cannot well be allowed to rise above 212 degrees Fahr., but this temperature of the jacket water might conceivably result in cooling the metal too much, particularly if the cylinder bore is small and the walls thin.

Engines having water cooling systems should receive more careful attention perhaps than those having air or oil cooling systems. Water left for any length of time when the engine is not being used, will gradually find its way through the packing at the cylinder head, causing corrosion in the inlet and exhaust valves. When the work for the season has been completed the water should be drawn off and the valves left open. Cylinders may become overheated by the improper flow of water through the cylinder water jacket or through the accumulation of dirt or scales in the water jacket.

The water supply and feed should be very carefully

watched in the operation of gasoline engines, as it is very often the seat of annoyance and not infrequently serious trouble. Pure, clear water is about as easily obtained as dirty water.

Fans used for cooling the cylinders are of various designs, most of them having four, five or six blades.

The average speed of revolution is about 1½ times the speed of the engine. Fans consume but little power and serve to discharge the heated air away from the cylinders by replacing it with a constant current of cool air. These fans may be driven from the engine shaft by belt, gear wheels or friction drive. If the engine is water cooled, the system may be either the hopper cooling system or the closed jacket circulatory system. If [illegible] methods are used, it will be necessary [illegible] when the engine is not running, unless an anti-freezing solution is [illegible]

[illegible] most widely used preparations are wood alcohol, [illegible] the first named being [illegible] effect on either [illegible] or the water [illegible] is apt to attach [illegible] dissolves the rubber [illegible] motor.

[illegible] preferred, because [illegible] no faults, except [illegible] differs from glycerine [illegible] that it is [illegible] the water.

[illegible]

latitudes in which it is employed, and the following will give a good idea of what may be expected of the various proportions of the mixture:

A 10 per cent solution in water freezes at 18 above zero.

A 20 per cent solution in water freezes at 5 above zero.

A 25 per cent solution in water freezes at 2 below zero.

A 30 per cent solution in water freezes at 9 below zero.

A 35 per cent solution in water freezes at 15 below zero.

A 40 per cent solution in water freezes at 24 below zero.

It will be readily seen that a 30 per cent solution will be ample for all occasions. In many cases one filling of the radiator with this solution will last through the winter, but should any loss occur in the radiator equal parts of water and alcohol should be added.

Calcium chloride is a very effective cooling agent, but unless the chemically pure article is used, there is danger of corrosion of the metal with which it comes in contact. Crude calcium chloride retails at about 8 or 10 cents per pound, but the chemically pure article is worth about 25 cents per pound in small quantities. A solution of 5 pounds of calcium chloride to each gallon of water will not freeze at any temperature above 39 degrees below zero; but the following table will aid in preparing the proper solution for the different temperatures.

1 pound for each gallon of water freezes at 27 above zero.

2 pounds for each gallon of water freezes at 18 above zero.

3 pounds for each gallon of water freezes at 1.5 below zero.

3½ pounds for each gallon of water freezes at 8 below zero.

4 pounds for each gallon of water freezes at 17 below zero.

5 pounds for each gallon of water freezes at 39 below zero.

A convenient way to prepare the solution is to first make a saturated solution of the calcium chloride and water, that is, to mix with a quantity of water at 60 degrees Fahrenheit, all the calcium chloride the water will dissolve, and use equal parts of this solution and pure water. If chemically pure calcium chloride is used no trouble will result, but chloride of lime, often sold as pure calcium chloride, should be avoided.

Glycerine is an effective agent, and as it will not crystallize in the water jackets it is preferable in this respect to calcium chloride, and it has the further merit of not requiring any renewal during the season, as it does not evaporate. It is, therefore, only necessary to add pure water to replace that which has evaporated. Several solutions of glycerine and water, with regard to degrees of cold in which they may be safely used, follow:

A 10 per cent solution freezes at 28 above zero.
A 30 per cent solution freezes at 15 above zero.
A 40 per cent solution freezes at 5 above zero.
A 50 per cent solution freezes at 2 below zero.
A 55 per cent solution freezes at 10 below zero.

In using a glycerine solution care should be taken to thoroughly cleanse the jackets of any residue of crystals from a calcium solution previously used, as this residu will thicken and cloud the glycerine solutions and rer

them partially ineffective. Solutions of glycerine will thicken up when subject to low temperature, but will not solidify and, unless it does, it will not disrupt the piping of the radiator or the jackets of the cylinders.

Assuming that the wood alcohol is to be preferred on some counts as less liable to choke up constricted passages or attack the hose connections, and that outside these evils which are characteristic of a glycerine and water solution, it is a most desirable and substantial mixture; then it is well to consider the advisability of reducing the quantity of glycerine, and substituting alcohol instead. By the use of both wood alcohol and glycerine, the total proportion of water can be increased, and that is a step in the right direction on two counts, that is, cost and stability. The following combinations of half alcohol and half glycerine and water may be used.

A 10 per cent solution will freeze at 25 above zero.
A 20 per cent solution will freeze at 15 above zero.
A 25 per cent solution will freeze at 8 above zero.
A 30 per cent solution will freeze at 5 below zero.
A 35 per cent solution will freeze at 15 below zero.

A common solution of salt (sodium chloride) may also be used. It remains fluid down to 0 degrees Fahrenheit. An incrustation, however, occurs as the water evaporates, and it is claimed electrolytic action would follow its use. Common salt is cheap, but radiators are costly, delicate and composite in construction—that is to say, there are a plurality of metals in the makeup of radiators, hence electrolytic action would follow, due to the difference of potential nature to different metals immersed in a saline bath.

Water cooling for the gas engine seems to be by far the most used. Most engines used for automobiles are

of the water cooled type, the cooling being accomplished by a circulation of water from a tank or radiator to the jacketed walls of the cylinder. According to the laws of liquids the heated water will rise to the top while the cooler layers will fall correspondingly. This is known as the gravity system and will be found in use almost anywhere the gas engine is used.

The pump or forced circulation is much used and has advantages over the gravity system as it keeps the water continually moving from the jacket of the cylinder to the supply tank or the radiator, which being employed, a less quantity of water is required to cool the engine cylinder, or radiate the heat units. Efficiency of the gas engine depends much on the temperature of the water in the cooling system. The best practice is to supply water to the jacket at such a temperature that the hand can be held on the jacket, or in other words, below the boiling point. If steam is seen coming from the relief or outlet of the radiator, look for a stoppage in the pipes somewhere, though if the pumps are run in the wrong direction the result will often be the same. If the pump is to be tested, run the motor for a few minutes and ascertain how long it takes for the water to heat the top of the radiator tubes. It frequently happens that some of the tubes are hot while others are cool, in which case the trouble will usually be found in the pump. The pump is used because it gives a more uniform heat at all times to the engine cylinder and this, of course, adds much to fuel economy. The design of the cylinder should be such that as much of the surface as possible be exposed to the air, the greatest possible amount of freedom for the circulation of the water being the object. There are many types of radiators,

but the honeycomb and the tube with small fins are used to a great extent. Motors using the natural water circulation require from 5 to 5½ sq.ft. of radiation to the horse power. Generally speaking, the thickness of the water jacket space around the cylinder is ⅛ of the bore of the cylinder, while many vary from this. If water from the hydrant is forced around the cylinder so as to keep it cool, the heat from the explosion is cooled down so quickly by radiation that the expansive force is materially reduced, and this, of course, reduces the power with the same charge that would give good results with the water at the proper temperature. The object in using water is not to keep the cylinder cold, but simply to cool it sufficiently to prevent the lubricating oil from burning from the heat, for the hotter the cylinder the more power will be developed with the same charge drawn into the cylinder; providing the lubrication of the cylinder is not affected thereby. With the average engine, the consumption of fuel is more economical when under full load and the water temperature correct.

Starting Up on a Cold Morning.—If the engine is one which has the hopper cooling system, using water only, it is best to pour a pail of warm water into the hopper on a cold morning. This should be allowed to stand a few minutes before starting. It may be necessary to add boiling water if weather is extremely cold. This operation is more difficult if the closed jacket is used. In such a case it will be necessary to make a connection with the overflow water pipe which enters the top of the cylinder.

Another method of warming the cylinder is to lay a piece of heavy cloth which will absorb water very readily upon the carbureter or cylinder head or both, and

upon this pour steadily a stream of boiling water. The hot water method has proven very efficient, and is much easier than cranking an engine until the cylinder is warmed up enough for starting.

CHAPTER XIV.

LUBRICATION.

Engines which are air cooled require more lubrication in the cylinders, as well as a heavier oil because the temperature of the metal is invariably higher than where the water cooled system is in use.

An oil suitable for this purpose must have three characteristic points, i.e., a good body, low in carbon, and lastly, it must have a very high fire test. That is, the temperature at which the vapor coming from the oil would ignite should not be lower than 500 to 600 degrees.

Any lubricant leaving a large amount of carbon or residue should be carefully avoided.

For the crank and crankshaft bearings, the same grade of lubricant as is used for the cylinder gives the best results, and the amount should be three to four drops per minute with the gravity system and a proportionately small amount with the force feed system.

This method of lubrication is now being adopted on a large number of gas engines because of its reliability. A tank holding a quantity of oil is located at some convenient point on the engine. A small force pump is worked from the crank, or camshaft, as the case may be, and forces the oil through brass or copper tubes directly to the bearings and by means of check valves located at the pump and also near the sight feed a pres-

sure of several pounds to the square inch is obtained and each drop of oil is assured of reaching the proper place. This system requires practically no attention other than refilling of the tanks.

Where grease cups are used the caps or plungers should be screwed down at least two turns each hour. If a small quantity of graphite, about one tablespoonful to one pound of grease is used, one full turn of the cap or plunger each hour will be sufficient. The graphite and grease should be thoroughly mixed before filling the cup.

The fact that the lubricators are feeding is not a sign that the oil is reaching the proper place. Be sure the ducts are open and the lubricant goes to the bearing.

Where the splash system of lubrication is used the oil holder or base should be carefully cleaned before each filling. Wipe the inside of the holder with waste or a piece of cloth, being careful to remove all the particles of grit and sediment which will collect on the sides and bottom.

Cylinder Lubrication.—In cylinder lubrication extreme caution should be exercised. Just enough oil should be used to thoroughly lubricate the piston and no more. An excess will be burned by the high heat, and will form carbon on the rings, cylinder walls and piston. This carbon will, in a short time, become heated, causing pre-ignition and in a four-cycle engine frequent regrinding of the valves will be necessary. The piston rings will also stick, causing them to wear uneven, and thereby much of the compression will be lost, as well as a large amount of the power which should be delivered.

From eight to ten drops of oil per minute should be delivered to the cylinder, where common cups or in

other words, where the gravity system is used. With force feed this amount may be cut to five or six drops a minute, as they are much larger. An excess of oil in the cylinder will make itself known by the smoke from the exhaust pipe.

Testing Oils.—Many animal and vegetable oils have a flashing point suitable to use in the gas engine cylinder, and yield a fire test sufficiently high to come above the requirements, but they contain acids that are injurious to the metal surfaces which they are intended to lubricate.

A very simple test to detect acid in an oil is with blue litmus paper, which will show a pinkish color if there is any acid present. Another sensitive test, and a very practical one, is to partly cover a polished steel plate with a strip of flannel or lamp wick saturated with the lubricant to be tested. Expose this to the sunlight for about twenty-four hours. When the plate is wiped dry, if the lubricant is free from acid, the steel will have retained its gloss. If dull spots have developed on the surface covered, it is the sign of the presence of acid.

The cold test is of great importance in all lubricants. Any kind of oil is subject to low temperatures at times if in cold climates. The cold test temperature is the point at which the oil congeals. In order that an oil may feed properly at all times it must have a very low cold test. Too low a cold test should not be demanded, however, as any advantage there is gained by a sacrifice in the heat tests.

One requirement of a perfect lubricant is that it be consumed entirely or not at all, by the combustion in the cylinder. This would prevent all sooting due to the lubricant. Graphite fulfills the last requirement. It is

not affected in any way by the temperature obtained in a gas engine cylinder. It forms a smooth coating over the surfaces. All microscopic grooves and holes are filled with it. It keeps the surfaces apart and improves compression by actually making the piston larger and the cylinder smaller. It helps to prevent binding of the piston. The use of graphite alone is not advised. But its good properties added to those of oil make their combination an excellent lubricant for cylinders and also bearings.

It is not advisable to feed graphite in a common gravity feed oil cup. It may clog up the passage and cause trouble. It is often put into the cylinder through the spark plug hole with a bug gun, or blown in with a tube and quill. One should never use more than a small teaspoonful for every pint of oil used. When a piston is taken out it should be thoroughly rubbed with graphite after being cleaned. Also any bearing and shaft when taken apart. Always use the fine graphite which is prepared especially for use where oil is also used.

Soot in the Cylinder.—Soot in the cylinder may be removed at intervals without any particular amount of trouble if taken in time and not allowed to go for too long. Remove the spark plug and inject a small amount of kerosene and move the piston back and forth to allow the carbon deposit to be cut up by the action of the oil. Gasoline will not answer the purpose, owing to its rapid evaporation. It is a very good practice to clean the engine at regular intervals, the frequency depending, of course, on its use. The cranks should be disconnected, the cylinder heads removed and the piston drawn from them. The cylinder may then be wiped out with a cotton rag saturated with kerosene, the piston and rings

A knock caused by an over-rich mixture is very similar to that caused by too early spark. A very rich mixture is very slow to ignite, and in many cases can be made so rich it will not ignite at all. If retarding the spark from the extreme fails to overcome the knock, it can generally be reduced by closing the throttle sufficiently to give more air and less gas. Advancing the spark to the extreme when the engine is running slow will many times cause a very ugly knock. The spark advance should be gradual as the engine gains in speed. Other causes of pounding in the cylinder, such as premature or self ignition, is a heavy pound, and unlike the sound caused from the early spark or the over-rich mixture. The knocks caused by some other defects are in no way as severe as the above-mentioned. Among some of the other causes of less importance is a lack of lubrication. This trouble should have immediate attention as soon as discovered as it will cause the cylinder to overheat and seize. A weak spark will cause a knock or, in other words, a sharp puffing sound.

CHAPTER XV.

HORSE POWER CALCULATIONS.

Indicated Horse Power.—This is a computation based upon the mean effective pressure developed at each explosion and is usually calculated from the same formula used in connection with steam engines: I. H. P.$=\frac{PLAN}{33{,}000}$ where P=mean effective pressure; L=length of stroke (ft.); A=area of cylinder; N=number of explosions per minute. This formula does not discriminate between mechanical friction and losses in "fluid" friction. To get accurate results it is necessary to obtain the mean effective pressure after measuring the indicator diagrams recorded during both "power" and "cut-out" cycles as also "compression" and "suction" cards.

It requires a considerable knowledge of gas engine practice to make use of the above formula. What is needed is one that is more arbitrary and fits the majority of cases and, moreover, requires the use of only a few facts, such as the diameter of cylinder, length of stroke and revolutions per minute. Such a formula will be of great value in estimating the probable power a gas engine should develop if well designed and properly built.

Such a formula is given as follows:

$$\text{I. H. P.}=\frac{V\times \text{r.p.m.}}{10{,}000}$$

If it is a two- or four-cylinder engine, then multiply by the number of cylinders, as follows:

$$\frac{5 \times 5 \times 7 \times 400 \times 2}{16{,}000} \text{ (Cyl.)} = 8\tfrac{3}{4} \text{ h.p.}$$

In this formula the letters R. P. M. mean revolutions per minute.

Another rule is as follows: Let D represent diameter of cylinder in inches; L length of stroke in inches; R number of revolutions per minute; N number of cylinders.

Four-cycle: $\frac{D \times L \times R \times N}{16{,}000}$ = h.p. delivered approximately.

Two-cycle: $\frac{D \times L \times R \times N}{13{,}000}$ = h.p. delivered approximately.

CHAPTER XVI.

GASOLINE ENGINE TROUBLES.

To those who are inexperienced in the use of gasoline engines there are a great many things that are confusing. Usually the great trouble is in starting one of these engines even though the rules are followed. There are three or four prime reasons which prevent an engine from starting: The battery may be out of order, there may be water in the cylinder, the cylinder may be flooded, or the air is too cold and does not permit of the proper evaporation of gasoline. If the battery is a source of trouble, the first reason may be because of old age. An old battery may give indications of being strong, while in reality it is not strong enough to produce ignition. To test a battery without a testing meter is an easy matter, but this, of course, does not locate the weak cells and only gives information concerning the battery as a whole. In testing a battery disconnect the wires attached to the engine and bring the free ends together. If the battery is worn out a yellowish colored flame is produced as the two wires come in contact. If the battery is in a healthy condition there will be a dark blue or greenish flash. Another cause pertaining to the battery might also be found in a loose connection between two cells. The lock nut or thumb screw may be worked loose due to much handling; moving from place to place, if a

portable engine is used; or by the vibration of the engine when the battery is attached to the engine skid or bed. Again, a person may find trouble in the leads or wires which connect the battery to the engine. This is usually a broken wire inside of the insulation. When the insulation is broken, such a break is very easily found, but if the insulation is not broken then it is much more difficult to locate the trouble. A good method to use in discovering this break is to hold the wire between the thumb and forefinger and with the other hand pull it through slowly. If the wire is moved carefully back and forth or up and down as it passes between the fingers the break will be easily detected.

If, after properly inspecting the battery and all its connections, everything is found satisfactory, it would be well to investigate the igniter. There are times when water forms in the cylinder and collects upon the igniter points. This acts as a continuous connection between the two points and the electric current is not broken when the contact is broken. Lubricating oil sometimes acts in the same way when an excess is used. It takes but a moment to remove the igniter and if such obstruction is found it is easily remedied. If an excess of water is found in the cylinder when the igniter is removed, it will be necessary to remove the cylinder head and repack in order to prevent such a leakage. Another case which might be cited at this point is the over-charging of the ingoing air, which often results in what is termed flooding, that is, too much gasoline is admitted for the amount of air that is being taken into the compression chamber. The gasoline does not evaporate and is drawn into the cylinder and acts to a certain extent as water.

If an engine does not start after two or three turns

it is best to investigate the battery, as has been explained, in order to prevent this flooding. The best method to remove moisture in the cylinder when the engine is flooded is to open the air cocks on top or on the bottom of the cylinder, if such are provided. If not, hold the exhaust valve open and crank the engine until the moisture is expelled. It is more difficult to tell when the moisture has disappeared if the air cocks are not provided, and probably the best method for determining this is to crank until you believe the moisture is out and then turn on the battery. If it is nearly removed and you now close the exhaust valve and give the crank one or two turns, you should receive a slight explosion, indicating that the cylinder is not dry enough to attempt starting. If in the case of the air cocks, place the hand near the outlet and note if there is an appearance of gasoline as the air is driven out. If not, the same methods may be pursued as spoken of concerning the exhaust valve.

Winter weather often causes more or less difficulty. The chief trouble is the slow evaporation of the gasoline. This can be overcome by applying internal or external heat. Some cylinders are provided with a primer for the purpose of charging the cylinder before the feed is opened. This method is found quite satisfactory, but also has its objections. An engine exposed to extreme cold, even if provided with a primer, is very liable to refuse to run and it will be necessary to resort to other methods.

Air Locks in the Fuel Pipe.—An air lock between the carbureter and the supply tank can occur only when the pipe at some point between the tank and carbureter rises to a level higher than the carbureter, after having been some other point nearer the tank below this level. If

the pipe is thus bent, it will be impossible for the air in the pipe to escape at any point other than through the carbureter float valve when the tank is filled. After the pipe has once been cleared of air its action will be as good as that of a straight or direct pipe, unless the hump of the bend is quite high and the flow through the pipe sluggish. If these conditions obtain it is often found that in hot weather the fuel in the pipe will be partially vaporized, and that this vapor will accumulate in the pipe at the rising bend, thus preventing the flow of fuel to the carbureter. This is most apt to occur if the lower parts of the pipe pass in close proximity to the exhaust pipe or other heated part. In such a case vapor will accumulate at the highest part, and may become present in such quantity as to stall the engine before it can be cleared out in the natural course of events. The remedy is so to arrange the pipe line that it is either a steady rise or drop from tank to carbureter, or is of U-shape with no points other than ends higher than the lowest point.

Engine Fires Irregularly.—If the engine fires irregularly it may be due to any of the following causes: Insulation broken on wires, causing a short circuit in the electric current. The contact at the timer may be poor, or the terminals on the coil may be loose or corroded. The spark plug may be cracked, or the points not properly adjusted. They should be about 3/32 of an inch apart. In case of a weak battery they may be closed a trifle. The fuel supply may not be regulated correctly; it might be so rich it will not ignite, or so weak it cannot be ignited; in either case the engine would run irregularly. The spark coil may be poorly adjusted, or the platinum points pitted and stick.

Sometimes an engine will fire regularly but have no power. In this case it may be due to poor compression, which is due to worn or broken rings, broken or warped valves, leaky gaskets, scored or worn cylinder walls and weak valve springs. The fuel mixture may be weak, or lubrication poor. Muffler may be stopped with a sooty deposit until the back pressure will destroy the power. The exhaust valve may be lifted only part way, not allowing the burned charge to be expelled from the cylinder.

Broken Spark Plug.—A hissing sound can be caused by a broken spark plug allowing the compression to be forced through the fracture, or by the compression blowing past the rings. A cracked exhaust pipe, or an open compression cock, will emit a hissing sound, as will a blown gasket between the exhaust pipe and the muffler.

Loss of Power.—In case the engine runs but seems to have no power, look for the following: Over-rich mixture, caused by too much gas and not enough air; weak mixture, caused by too much air and not enough gasoline; loose or slipping fly wheel, insufficient lubrication, valves in bad condition, worn or broken rings, weak batteries and water in the gasoline.

If the engine has been running well and gradually slows up, missing explosions, look for trouble in the fuel supply, or fouled spark plugs, insufficient lubrication, weak batteries, wiring defective, being nearly broken and hanging by a thread, or loss of compression.

Explosions in the muffler are due to any of the following: Exhaust valve stuck, weak mixture failing to burn in the cylinder and burning in the muffler, weak spark not firing the charge until the working stroke is nearly finished. In this case it will not burn while passing to the muffler.

The water getting too hot, causing overheating, is generally caused by some of the following: Clogged pipes, incorrect timing of the valve, fan not working, pump broken or disconnected, oil in the water, muffler stopped up and a very late spark. In case there are explosions in the mixing valve, or carbureter, look to the intake valve or its spring. The valve may be broken or leaking, or the spring may be weak, not seating the valve properly, or the mixture may be weak, late spark, or the valves incorrectly timed. When the engine begins to knock it should be stopped at once and some of the following examined: Flywheel may be loose on the shaft, or the cylinder may be loose, rings may be broken or badly worn, bearings may be loose and need tightening, carbon deposit on the cylinder head, spark occurring too early, over-rich mixture, loose cross head bearing, and defective lubrication—this will cause knocking when the piston is about to seize. Finally, see that all parts of the carbureter are clean; that the float feed is free and does not bind, and that clean gasoline free from water is fed to it. A single particle of water at the needle valve will put the whole thing out of business. But water will settle at the bottom of the float feed chamber. Drain this off occasionally into a glass to see if there is water in it. This will show at a glance, for the water and gasoline will remain unmixed. A good separator and strainer in the gasoline feed pipe will cure this too frequent cause of trouble.

A Few Don'ts.—Don't try to start before first turning the switch on, or without fuel and lubricating oil turned on.

Don't start with the spark in an advanced position; a broken arm may be the result.

Don't use poor or worn insulated wire.

Don't wear your engine to pieces if it will not run. The trouble will in all probability be located by one of the following tests. Turn your engine over and see if the compression is correct; see if you have a spark; see that the gasoline supply is correct and has no water in it; see that the needle valve of carbureter is not clogged with dirt; see that the engine valves are not stuck and that they seat quickly.

Don't fail to read instructions on starting the engine.

Don't forget to keep cylinder lubricator filled and feeding. A dry piston will greatly reduce the power and cut the cylinder or piston.

Don't think that the cylinder should be perfectly cold. A gasoline engine works best when it is warm.

Don't keep the cylinder too hot or too cold. See that the air has full circulation. It is as necessary as gasoline. An engine cannot pull a load if overheated.

Don't forget to throw switch out when engine is not in use.

Don't fail to use the kind of cylinder oil recommended by the maker. It may be better than the more expensive grades.

Don't try to wipe engine while in motion.

Don't use too much gasoline. The engine develops the most power when working on a smokeless mixture. A black smoke coming from exhaust means too much gasoline; a blue smoke means too much lubricating oil.

Don't try to start engine with cylinder full of gasoline. Shut off same and turn engine over a few times before trying again.

Don't fail to see that everything is ready before trying to start engine.

Don't forget that nine times out of ten when the engine will not run you are at fault. Look around you and see what you have forgotten. It does no good to turn over the engine if conditions are not right.

Don't fail to look your engine over carefully when it is in first-class condition. You will then know how to fix it when something goes wrong.

Don't fail to have a fine gauze screen put in your funnel and strain all gasoline put in the tank.

Don't allow the working parts of engine to knock or hammer. Pay special attention to the connecting rod and keep it as tight as will allow engine to turn easily and run cool.

Don't think your engine will not wear out and that it does not need some care.

Don't be afraid to try to fix your own engine. You cannot tell what a good job you can do until you have tried.

Don't allow dirt or dust to accumulate on top of your batteries, as there is danger of short-circuiting them.

Don't forget to see that the wires are tight on the batteries, and that they may become exhausted in five or six months.

Don't run electric bells with engine battery, and don't let your engine stand outdoors without some cover for protection from rain. If the batteries become wet they will be short circuited and become useless.

Don't forget to look into the gasoline tank before sending for an expert. This seems simple but it has been omitted many times at great expense.

Don't screw the spark plug in too tight—just enough to prevent leakage and hold firmly.

Don't use a wrench on the upper nut of the spark plug; you may break the porcelain.

Don't forget to turn off the gasoline or lubricating oil when through running engine.

Don't run engine without water turned on.

Don't forget to draw off the water from the cylinder in freezing weather.

Don't place the coil and batteries so they will get wet.

Don't tinker with the carbureter as soon as engine misses—it may be the ignition.

Don't screw the vibrator down too stiff—your batteries will not last as long, and you will get no better results.

Don't try to start the engine with the carbureter throttle wide open.

Don't try to wipe the engine while it is running.

Don't forget to fill the fuel tank.

Don't forget to fill the oilers.

Don't allow water to accumulate in the muffler. It will either cause loss of power or stop the engine.

Don't fail to have an extra set of batteries and spark plug on hand.

Don't be afraid to study your engine.

Don't look for leaks in the gasoline pipe or tank with a lighted match.

Don't fail to provide suitable foundation for the engine.

Don't fail to remember if the gasoline gets afire that water only spreads the flames; use a fire extinguisher, sand or blanket. If the gasoline in the carbureter catches fire, turn off the fuel at tank and open the throttle wide —it will draw the flames into the cylinder and do no harm.

Don't get excited.

Don't bolt a magneto on to an iron or steel bar—use brass or aluminum.

CHAPTER XVII.

TYPES OF GASOLINE AND OIL FARM TRACTORS.

A large variety of gas and oil tractors has been put on the market within the past few years, and while the general principles underlying their construction are necessarily the same in all, yet each one has some special features which characterize it. In the following pages the leading types of tractors are described in detail, and the special features of each are brought out. The description of any one tractor to the exclusion of others would prevent a thorough presentation of much useful information, and yet it has not been possible to include all the tractors on the market. The only object has been to present enough to illustrate all the special features of the various engines.

BATES ALL STEEL TRACTOR.

Figure 54 shows the Bates traction engine which possesses in a high degree the merit of compactness and freedom of the working parts from dust and the inclemencies of the weather. The hood enclosing the engine and other working parts can be entirely removed when necessary. The cab also is easily removable.

The engine is of the two-cylinder opposed type and will develop 25 to 30 h.p. running at a speed of 500 r.p.m. The cylinders are cast separate from the crankcase and cylinder-heads, thus making it a very easy matter to replace the old cylinders with new ones, which it is claimed is cheaper than it is to rebore old cylinders.

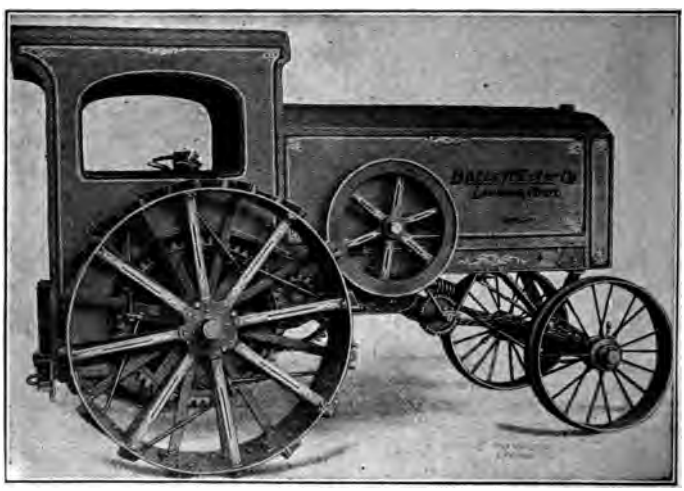


FIGURE 54.

The cylinder-heads in which the inlet and exhaust valves operate, are cast separate from the cylinder, and are fitted with a water circulation for cooling the valves. The valves are cast iron, with steel stems operating in guides of sufficient length to insure perfect alignment. The valve head on which the valve gear operates is made of hardened steel. The valve gear is very simple, there being but one cam and two valve rods to mechanically operate four valves. The piston is hinged to the connecting rod and is provided with rings. The connection

between piston and connecting rod is exactly in the [illegible] dle of the wearing surface, thus equally distributing the wear. The connecting rods, one of which is [illegible] Figure 55, are of the I beam type, [illegible]

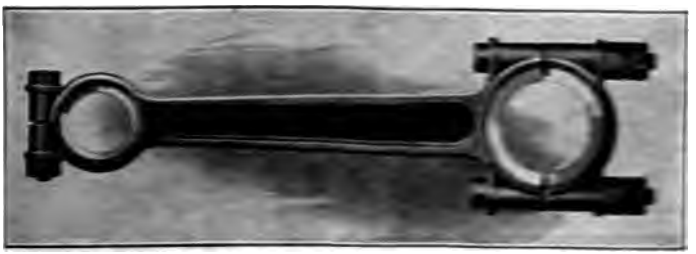
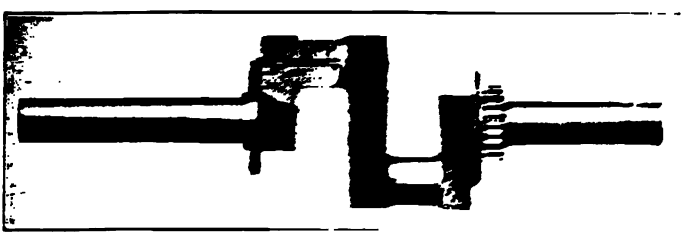


FIG. [illegible]

bitted bearings in the [illegible] end connecting with the [illegible]

The cranks, together [illegible] shaft, are made of [illegible]



[illegible]

tioned according [illegible] the [illegible] cating the [illegible] the [illegible] ugal force [illegible]

case. Transmission is arranged in the lower portion of the crankcase and is provided with two speeds, forward and reverse.

The gears are of steel. The friction clutch is of the periphery type, provided with one adjustment only. Positive clutches are in the transmission case, running in oil, and arranged so as not to be engaged or disengaged while the friction clutch is in service. They are also provided with means for preventing the use of more than one speed at a time. The governor is arranged on the camshaft and is of large diameter, giving a high peripheral speed, thus insuring complete control. The governor stem passes through the camshaft and operates on the throttle. Ignition is jump spark, current being supplied by dry batteries and slow speed magneto, gear driven. The cooler is of the enclosed type, arranged with interchangeable cooling sections, and holds 12 gallons of water. Figure 57 shows one of the sections removed. Oil can be used in place of water in freezing weather.

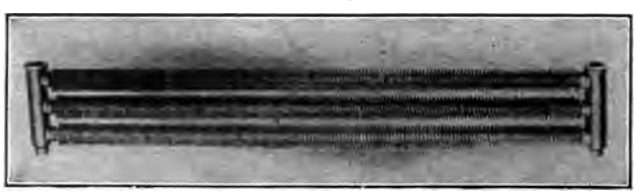


FIGURE 57.

The fan is 24 inches in diameter, with ball bearings running in oil. It is driven by a belt from the governor case through a set of bevel gears. Controlling levers, including steering wheel, speed changing wheel, clutch, spark and throttle levers are arranged on one column

within a radius of 12 in., thus providing a complete controlling system. The speed of the tractor can be changed from forward to reverse as quick and easy as a steam tractor.

The throttle lever operates directly on the governor, changing the speed from 300 to 700 r.p.m. and making it possible for the engine to receive a full explosion at its minimum speed. By this system the tractor can be driven very slowly, at the same time exerting a maximum tension on the draw bar.

The front wheels are 38 ins. in diameter with 8-in. face.

The drive wheels are 60 ins. in diameter with 18-in. rim. Spokes are flat steel bars firmly riveted to the rim and steel hub. Cone or cleat lugs are provided.

The master gear is of steel, 38 ins. in diameter with 4-in. face, provided with teeth with 2-in. pitch.

These engines are also provided with a friction clutch pulley to operate belt driven machinery.

THE SKIBO FARM TRACTOR.

Figure 58 shows a view of the Skibo farm tractor, a machine designed more especially to meet the requirements of those farmers who are operating small farms, say from 75 to 160 acres.

The frame of this machine is constructed of heavy channel steel securely riveted together and thoroughly braced with the motor hung low on the frame. This brings the center of gravity close to the ground, making the machine very stable and affording no tendency to racking the frame which is sometimes the case where the center of gravity is high from the ground.

The drive wheels are 61 ins. in diameter and 20 ins.

wide. The power to drive the machine is delivered from the rim of the bull gear to the rim of the drive wheel.

The front axle is centrally pivoted to the main frame to permit tilting of the axle in going over uneven ground.

FIGURE 58.
Skibo Farm Tractor.

The steering device is the automobile type, quick in action and absolutely positive, requiring very little attention from the operator. The transmission is entirely by spur gears, excepting the bevel gears comprising the differentials; all gears are of large proportion and ample strength, the main drive gear being 31 ins. in diameter with 4-in. face.

Figure 59 shows the engine used on this tractor, and it will be noted by the illustration that it is of the horizontal opposed type. The cylinders are 7½ by 7½, with heads cast separately. The crankshaft is 3½ ins. in diameter, worked out from solid steel. This shaft runs 500

r.p.m. and at this speed its inventors state the engine delivers from 38 to 40 brake h.p. The tractor is sold as an 18-25 h.p. machine, showing a power on the draw bar of 18 h.p. and on the belt pulley of 25 h.p.

All running parts of the motor are provided with positive means of oiling and in addition to this, the splash crankcase system of oiling is employed. Ignition is high tension jump spark produced by magneto; dry cells being used for starting. The motor is water cooled, the

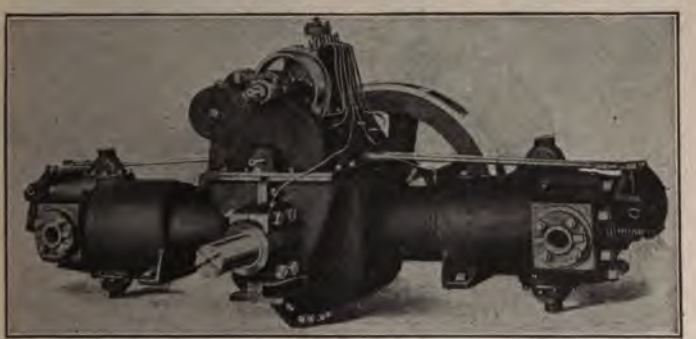


FIGURE 59.

water passing through a closed radiator which is cooled by air, a fan in front of the radiator causing a strong current of air to pass through the radiator.

This machine has two speeds forward, namely 2½ and 3 miles and reverse. It has a capacity of drawing 4 to 6 stubble plows, depending on the soil and lay of the land, and will pull 4 seven-inch binders or 5 six-inch binders. Its manufacturers state it will run a 32-in. cylinder threshing machine with feeder, wind stacker and weigher. It weighs 10,000 lbs.

An engine of this type is extremely useful in plowing,

pulling binder, and heavily loaded wagons. It is provided with a friction clutch belt pulley attached direct to crankshaft which enables the machine to be used for operating binders, shredder, corn sheller and in fact for all general purposes on the farm.

HUBER TRACTION ENGINE.

Figure 60 shows a view of the farm tractor manufactured by the Huber Manufacturing Company of Marion, Ohio. This farm tractor has a double opposed engine

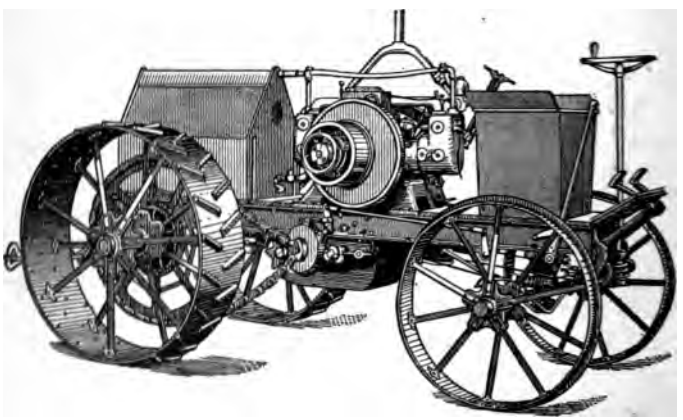


FIGURE 60.

with cylinders 5¾ by 6, rated as 9 nominal, 12 tractive or 20 brake h.p. All proportions are ample for heavy duty continuous service, bearings oiled by mechanical oiler and splash system. Under U. S. Government inspection, it showed a fuel consumption of ⅔ of a pint of gasoline per hour, for each horse power produced for a continuous run at maximum load for six hours

The transmission is the selective type sliding, similar to the automobile, except in the ample size to provide the proper strength. It has two speeds forward and one reverse, the gears being shifted from the driver's seat by a single lever. These gears are cut steel, run in an oil bath, protected from the dirt by suitable housing.

The power is transmitted from the engine to the countershaft by a roller chain and cut steel sprockets, the chain having an ultimate strength of 17,000 lbs. From the countershaft to the drive wheels a Jeffery Steel Thimble Roller Chain with safe working strain of 6,300 lbs. at 200 ft. per minute and ultimate strength of 48,000 lbs.

The mounting is on 6-in. channels, 10½ lbs. to the foot, hot riveted together. The length of the frame is 10 ft. 6 ins., width 24 ins. The rear drivers are 54 ins. diameter and 16-in. face, made of ⅜-in. boiler steel, the front wheels are 40 ins. diameter and 6-in. face, made of 5/16-in. boiler steel and with a wrought iron band in the center to prevent slipping. The rear wheels are provided with cleats and extra picks or spurs for plowing. The hubs have a 20-in. bearing. The rear axle is a 3-in. interchangeable and has babbitted bearings secured to the frame. The roller shaft, running the extreme width of the traction from out to out of drive wheels is 79 ins. Each tractor is provided with a plow hitch.

The control is from the driver's seat, which is in front. The guide is by hand steer wheel with worm and cable. Foot levers operate the clutch and brake, and a single hand lever shifts all gears. The engine is controlled by the governor, but the spark and throttle levers are accessible to the driver from his seat. The low speed,

which is the plowing speed, is 1.85 miles per hour; the high speed, for ordinary hauling on the roads is 2.80 miles per hour. These speeds being produced at the normal engine speed. Each engine is equipped with friction clutch, pulley for belt power and dry cells and coils for ignition.

The total weight of the engine with 15 gallons gasoline and water supply, with man on seat, is about 5,800 lbs.

The makers guarantee 2,500 lbs. draw bar pull and 12 tractive h.p. Actual test shows 2,750 lbs. draw bar pull under continuous load with engine running 635 r.p.m.

AULTMAN AND TAYLOR GASOLINE TRACTOR.

This engine, shown in Figure 61, is a four-cylinder, four-cycle type. The cylinders are cast in pairs, arranged parallel, and in horizontal position. The cylinder-heads are also cast in pairs, being secured to the cylinders by heavy stud bolts and provided with a copper gasket. The valves are seated in the heads, and a water jacket surrounds cylinders, combustion chambers and valves.

The pistons are cast from the same grade of iron as that used in the cylinders, and they are provided with four snap rings made from a special mixture of hard gray iron.

The motor base or crankcase is fitted with an oil-tight, dust-proof cap, which, when removed, permits the cranks, camshaft, connecting rods, and pistons to be withdrawn from the crankcase without disturbing any

other parts or adjustments. The lower bearings of the crank and camshafts are cast as a part of the crankcase, thus insuring perfect alignment. The lower parts of the bearings are babbitted and the upper parts, which take the thrust and receive the greatest amount of wear, are made of a special grade of bronze. These are interchangeable and new ones can be put in in a very few

FIGURE 61.
"Aultman-Taylor" Gasoline Engine.

minutes, in case it is necessary to do so. The main bearings are adjustable from the outside of the case and are so easily accessible that they may be adjusted while the motor is running.

The crank-pin bearings are babbitted with genuine babbitt and the caps are secured to the connecting rod by bolts which are provided with slotted nuts, permitting

very fine adjustment and absolutely preventing the nuts from coming loose.

Connecting rods have adjustable bearings on the piston pin which is provided with a bronze bushing which is very easily removed and replaced by a new one if necessary.

The valves are all mechanically opened by plungers which are provided with hardened rollers, operated by pins made of special steel, hardened and ground. The cam rollers work on hardened pins which reduce the friction and wear to a minimum.

The speed is automatically controlled by a centrifugal governor which is driven by gears enclosed in the crankcase and absolutely protected from dust. The governor acts directly upon the throttle valve and the speed may be varied from one to five hundred revolutions by simply moving a lever which is set near the steering wheel. Battery and magneto systems are both provided for ignition.

The battery consists of fifteen primary battery cells, hermetically sealed in water-tight cases so that there is no possibility of their becoming damaged by moisture, and will last for an indefinite time when the battery is used for starting only.

The carbureter is of the floating ball type; has no spring air valves; no spring adjustments and in fact requires no adjusting whatever except to change the amount of gasoline fed to the motor.

Fuel is carried in a large reservoir placed under the platform and below the engine, and is pumped into a small reservoir above the motor by an automatic pump.

The magneto is of the low tension type and of the simplest construction, having no brushes or commuta-

tors to adjust. It is positively driven by cut gears direct from the camshaft of the motor and is provided with water- and dust-proof cover.

Wires are carried from the magneto to the spark plug through a metal tube, which prevents them from becoming damaged or in any way short circuited. This obviates one of the old annoying troubles of a gas engine. The spark plugs are set in the head and are easily removed. Any type of standard spark plug can be used.

Lubrication is effected by means of a multiple force feed oil pump which forces a definite amount of oil through an individual tube to each bearing and also to each cylinder.

The crank pins are positively oiled by centrifugal oil rings fastened on the crank. These rings receive their oil from the force feed pump and force it directly to the crank pin bearings. This system insures continual feeding of fresh oil to the cylinder and all the bearings.

The method of transmission is by means of spur-gears of extra wide face and simple in construction. The power is taken from the motor by a steel pinion, 4½-in. face, 1½-in. pitch, on the crankshaft, which pinion drives the differential gear through steel intermediate gear, both having 4½-in. face and 1¾-in. pitch.

The bull pinions are all steel 5½-in. face, and 2¼-in. pitch. The bull gears are semi-steel, provided with hubs and spokes to insure centering. They have heavy adjustable torsion rods by which they are securely fastened to the rims of the drivers and take up all of the driving strain.

The reverse pinions are of cast steel, with extra wide faces. The gearing and all the transmission bearings

are oiled by a multiple force feed pump, which drives a definite amount of oil to each bearing and is positively driven from the countershaft so that it operates only when the engine is running.

The forward and reverse movement of the engine, also the belt pulley, are controlled by two clutches which are operated by one lever.

The backing up gear and the belt-pulley are operated by the same clutch which is of the internal expanding type and clutches directly on the under side of the pulley rim. But one lever is used for both forward and backward movement.

The engine runs at 500 revolutions per minute. Speed on road at 500 revolutions per minute is 2.2 miles per hour.

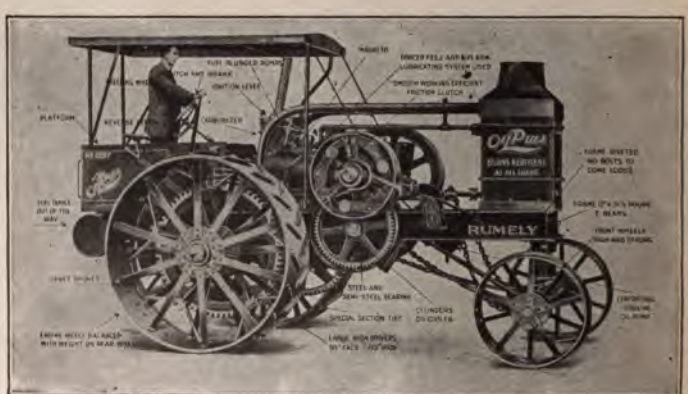


FIGURE 62.
Rumely Oil Traction Engine.

RUMELY OIL ENGINE.

Figure 62 shows the Rumely oil traction engine, in which kerosene is used as fuel. It is claimed that kero-

sene is the most concentrated fuel obtainable at any price, and also that it is the most universally distributed.

The Rumely oil engine is a four-cycle engine with two cylinders of ten-inch diameter and twelve-inch stroke, Figure 63. Cylinders are cast, machined and finished singly, and then solidly bolted on the crankcase

FIGURE 63.

in a horizontal twin construction. The cylinders and cylinder heads are surrounded on all sides with jacket for cooling. The heads can be easily removed by unscrewing ten bolts without disconnecting any other parts.

FIGURE 64.

The piston, Figure 64, is equipped with five self-expanding rings. The connecting rod is of drop-forged steel construction. Crank-pin bearings are made in halves and lined with shells of special metal.

The crankcase is covered with a sheet steel lid that

shuts out all dust and dirt. This cover can easily be removed at any time by unscrewing the bolts that hold it in place. It is constructed with this cover on top instead of on the side or end, which permits of easy access to any working parts in the crankcase.

To further facilitate the accessibility to working parts in the crankcase, a secondary cover is provided which can be removed easily. This opening is large enough to allow the operator to reach any point within the crankcase.

All cams are key-seated upon the camshaft with double key-seats, which absolutely prevent any possibility of slipping or alteration in the timing of the engine. The exhaust and intake valves are mechanically operated. The valves are constructed with steel stem, nickel-steel heads.

Valve cages are oil-cooled, thereby eliminating all possibility of the valves overheating or warping. The valves themselves can be removed by unscrewing the connection. The engine is provided with a set of relief cams by which the compression can be relieved—this greatly facilitates the starting of the engine.

Lubrication is effected by a combination of mechanical and splash methods. Six feed pipes enter the crankcase, one to each bearing, and two feeders force oil into the cylinders. The crankcase contains two gallons of lubricating oil, and is so arranged that any surplus of oil can be drawn off at any time.

Hard oil or grease cups are placed on every moving part that requires constant oiling. To be sure that the entire engine is properly lubricated, it is only necessary to see that the oil cups are properly filled and turned down regularly when the engine is working.

ignition system is of the make-and-break type,

operating with a low tension current. A double supply of current is provided by a set of dry battery cells and a magneto which is operated by gearing, see Figure 65.

In order to secure the best results in an oil-burning internal combustion engine, water must be used. The quantity of water must vary with the load. If too much is introduced, the cylinder is flooded and the engine is killed; if too little, the desired effect is not obtained. At the moment of the explosion the water is evaporated and disassociated into its elements of hydrogen and oxygen.

FIGURE 65.

This free or nascent oxygen attaches itself to any free carbon and exerts a scouring effect in the cylinder. As the piston stroke advances and the temperature drops, hydrogen again turns to water and liberates its heat, thus keeping up the pressure. This and certain other results are obtained by the use of water, providing the admission of water is as carefully proportioned as that of fuel. The Higgins carbureter is used and this device controls not only the intake of oil, but regulates also the quantity and proportion of water in accordance with the needs of the engine.

The valves are in cages, therefore easily removable, with one or more mathematically proportioned air passages, and is connected with the governor in such a manner that it is absolutely positive in its workings.

FAIRBANKS-MORSE OIL TRACTORS.

This tractor is built in two sizes. The smaller size, a light, medium power tractor, will, it is claimed, do the same amount of work continuously in plowing or hauling on level ground as 15 heavy horses will do; and will give to a belt, driving a thresher or other machine, 25 horse power. The larger size tractor is rated at from 30 to 60 horse power. It has two cylinders, 10½-inch bore by 12-inch stroke. Its normal speed is 375 r. p. m., and it will develop at this speed 70 brake horse power.

This engine is fitted with throttling governor, air heaters and water reservoir for the use of oil fuels, and it will successfully handle gasoline, naptha, kerosene, low grade distillate and similar oils, which gives it a wide range of fuels. Speed regulation is very close, giving practically the same speed at full and no load, and there is no undue variation or speeding when load is suddenly thrown off.

The two cylinders are cast together. See Figure 66. This is in line with the most recent automobile practice. It permits cylinders to be brought close together, reducing length of crankshaft, gives an easy water circulation through jackets, simplifies all pipe connections, and when bolted to the frame, makes a construction so strong and rigid as to insure against springing or breakage.

The combustion chamber has no pockets, all valves closing flush with inside of cylinder. This construction gives the least cold surface exposed to the hot gases, therefore less heat goes away in the jackets and more goes into power.

FIGURE 66.

Main Engine Frame, with Cylinders in Place.

The pistons come out without removing any shafts or cylinder heads. This point of easy access to all wearing parts, adjustments for wear, and easy replacement of worn parts, is of the utmost importance.

The valves are in cages, therefore easily removable, and the valve operating mechanism is very simple.

Figure 67 shows two views of the cylinder head casting, in which the valves operate, and it is self-explana-

tory. Figure 68 shows the piston, piston rings, piston pin and connecting rod of one engine. Figure 69 is a view of the crankshaft as it appears in the rough and after finishing. It is cut from a solid billet of steel and is 5 inches in diameter in the bearings and 5½ inches in

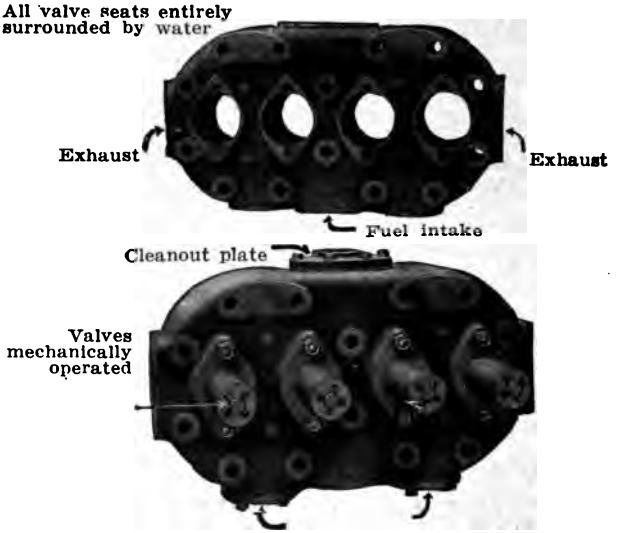


FIGURE 67.
Cylinder Heads, Showing Valve Cages Removed and Also in Place.

the crank pins. The two cranks are set in line, no bearing being used between the cranks.

The fuel tank holds 80 gallons.

The belt pulley is located on the right hand side of the engine and the clutch is operated by a lever from the footboard, which makes it unnecessary for the engineer to get down on the ground to disengage the clutch to stop the driven machine.

The transmission is of the shifting gear type with hardened steel gears. The transmission gears are

enclosed in a practically dust proof case, this being connected with enclosed crankcase and better providing for

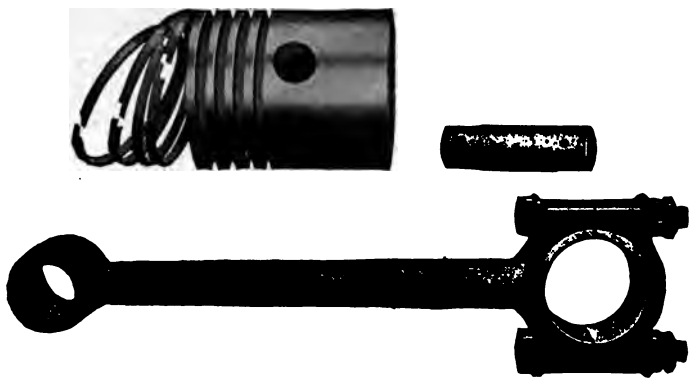


FIGURE 68.
Piston, Piston Rings, Piston Pin and Connecting Rod.

air displacement of the pistons. Power is transmitted to the truck through the clutch on the left hand side of the engine, which is operated by combined clutch and shifting lever on the footboard. This lever has an interlocking device, arranged so that it is impossible for the operator to shift the gears before the clutch is disengaged, or to engage the clutch until the gears are completely in mesh. It is also impossible to get two sets of gearing in mesh at one time and prevents any possibility of stripping gears by applying the load on the corners of the teeth.

The drive wheels are 78 inches in diameter, with a 30-inch face. These give a very large bearing on the ground which is particularly desirable when using the engine for cultivating or seeding on plowed ground. The front wheels are 48 ins. in diameter, 14 in.-face. The wheel base is long and the engine is easy to guide. The drive wheels are covered by a metal housing which

protects the operator and the working parts of the engine from dust and mud.

This engine gives a drawbar pull on low gear of 9,000 lbs., which will haul from eight to twelve 14-inch plows, according to the character of the plowing. The hitch is

FIGURE 69.
Crank Shaft, Rough and Finished.

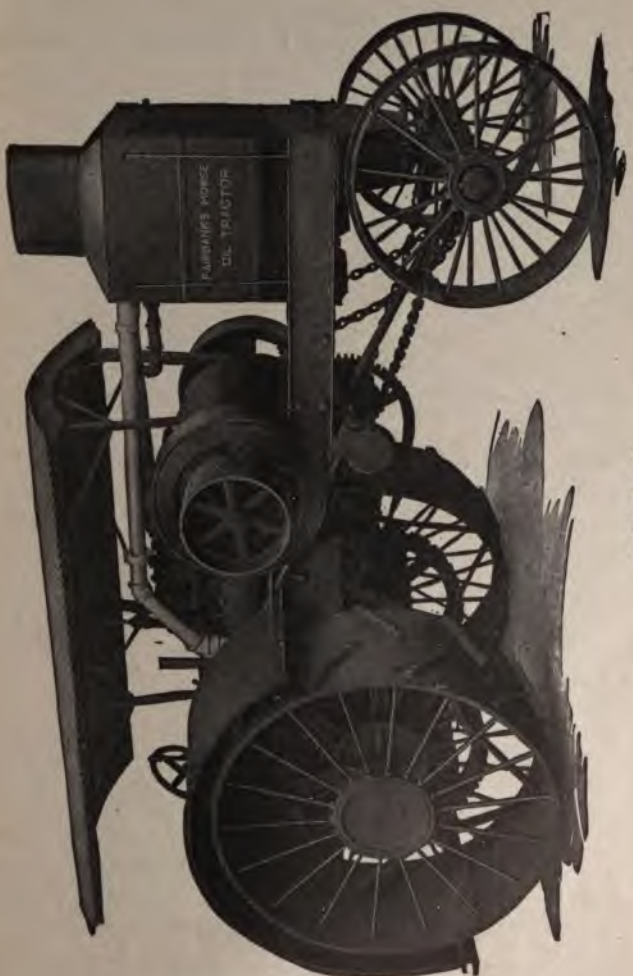


FIGURE 70.
Fairbanks-Morse 30-60 Oil Tractor.

placed about 18 inches above the ground and consists of a heavy bar extending approximately to the middle of the bull wheels on each side, thus providing for hitching the load most satisfactorily.

A 9 feed force feed oiler divided into two compartments is sued, one compartment being used to force the oil to the cylinders and engine bearings and the other compartment being used to force the oil to the gearing of the transmission.

The cooling water is kept in circulation by a positively driven centrifugal pump. From the engine it passes to a closed radiator which effectively cools the water without loss. This radiator holds about 100 gallons. The transmission operating mechanism has but one lever with which two speeds forward and one reverse speed are obtained. The transmission clutch is operated by a separate lever.

The crank bearings, cams, and open end of each cylinder are protected from dirt by a tight-fitting steel cover.

The engineer's platform is roomy, which gives the operator a clear view of the road ahead. All operating devices are within easy reach.

The bearings which are equipped with grease cups are those also which are liable to receive some dust. Lubricating oil is so thin that dust, sand, etc., can work into an exposed bearing. On the other hand, the grease forms a film all over the bearing, and gradually is forced out at the end by the pressure of the incoming grease.

The ignition is jump spark, the equipment being a gear driven magneto, two cylinder timer with platinum contact points, two unit spark coil with master vibrator, and extra large mica insulated spark plugs.

This engine has two speeds forward and one reverse.

FIGURE 71.

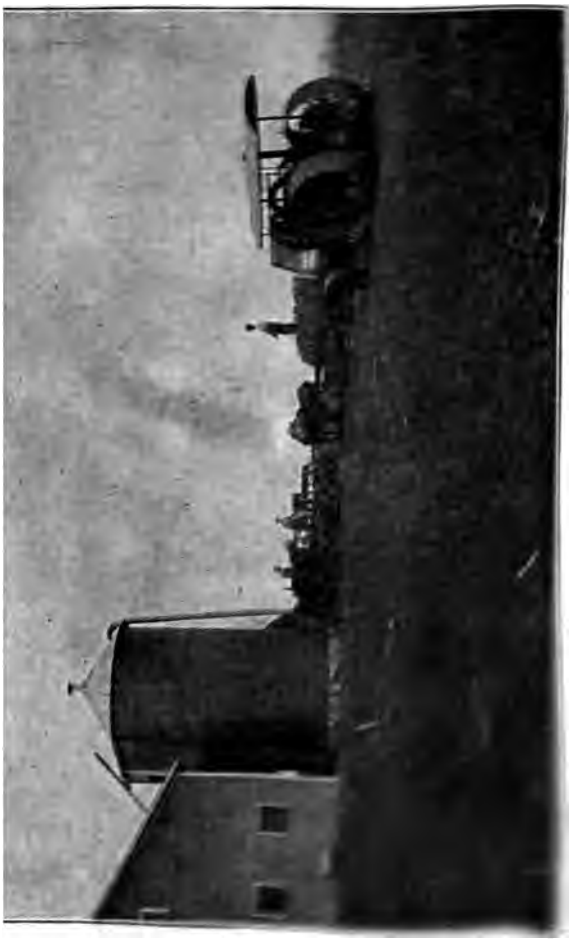
15-25 H.P. Oil Tractor Pulling Two 7-ft. Disc Spaders, One 8-ft. Wheel Disc and One 3-Section Harrow, Taking the Place of 15 Draft Horses and 3 Drivers.

The forward speeds are 1¾ and 2½ miles per hou
and the reverse 1¾ miles per hour.

FIGURE 72.
15-25 Oil Tractor Threshing in Washington.

The engine will operate equally well on kerosene, l
grade distillate oils and gasoline. More than the f

l power may be developed on any of these fuels fuel is sprayed directly into the cylinder together



Elevating Ensilage.

a spray of water [illegible]
oad, being about [illegible]

Plowing.—In stubble plowing from ten to twelve 14-in. bottoms can usually be handled with this tractor, plowing to a depth of 5 ins. or 7 ins. With ten 14-in. bottoms about 24 acres in 10 hours can be plowed.

If intended for breaking only, and in tough soil, eight 14-in. moldboard breaking plows will be all that should be expected, but for lighter breaking and for stubble as many as twelve may frequently be used. The depth plowed for breaking is usually about 4 inches, some preferring to plow deeper and others not so deep. On account of the contour of the land affecting the number of plows that can be pulled, considerable advantage will be realized from the two speeds used on this outfit, the slowest speed being used in plowing in the hardest spots or on hills, while the higher speed is used on level ground and wherever the conditions are more favorable. With eight 14-in. plows about 20 acres can be plowed in 10 hours. Where the soil and other conditions will permit the use of a greater number of plows, a correspondingly larger amount of work can be done.

AVERY GAS AND OIL TRACTORS.

Figure 74 shows a view of the Avery tractor, which is built in three sizes by the Avery Manufacturing Company, Peoria, Ills. Simplicity and compactness appear to be the predominating features in the design of this farm tractor, and the claim is made by the builders that the motor is unusually economical in fuel consumption, as shown by numerous tests and in actual practice.

Either gasoline or kerosene can be used for fuel. The

FIGURE 74.
Avery Gas and Oil Tractor.

weight of the tractor shown in Figure 74 is about 7,500 pounds.

Motor.—The motor, two views of which are given in Figures 75 and 76, is of the opposed type. This style of motor permits of an extremely strong construction and is very simple. It requires no balancing counterweights on the crankshaft which are a constant source of trouble and repair expense. It balances perfectly and prevents vibration.

The motor runs at a low speed—500 revolutions per minute—which means that there is little wear on the parts. It is also placed lengthwise of the frame which makes it possible to drive the gearing direct from the crankshaft without the use of bevel pinions, which waste power and cause unnecessary repair expense. The sizes of the motors used on Avery tractors are as follows:

Rated Horse Power.	Style	Bore. Inches.	Stroke. Inches.
12 Traction—25 Brake H.P. Tractor	Two Cylinder Opposed.	6½	7
20 Traction—35 Brake H.P. Tractor	Two Cylinder Opposed.	7¾	8
40 Traction—80 Brake H.P. Tractor	Four Cylinder Opposed.	7¾	8

Figure 77 shows one of the connecting rods and boxing. The construction of the crankshaft is plainly illustrated in Figure 78. The crankshaft pinion meshes directly into the compensating gear when the motor is running ahead, thus dispensing with all idle gears in mesh and running, either when driving a belt or drawing a load. Figure 79 is a side view of the motor and gearing in the position for traveling ahead. Figure 80 shows the intermediate gear in different positions.

For belt work the sliding frame is pushed forward until the crankshaft pinion disengages from the com-

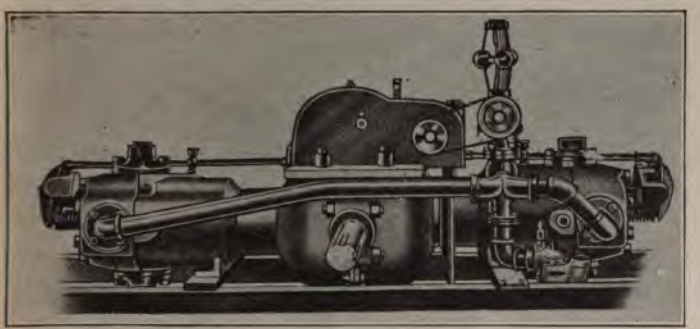


FIGURE 75.
Right Hand Side of the 20-35 H.P. Tractor Motor.

FIGURE 76.
Left Hand Side of 20-35 H.P. Tractor Motor.

pensating gear. The intermediate gear remains disengaged in the position shown by the dotted lines. See

Figure 80. In order to back up, the sliding frame is placed in the same position as for belt work and the intermediate gear, which is mounted on an eccentric, is

FIGURE 77.
Connecting Rod and Boxing on 20-35 H.P. Tractor.

drawn back to engage both the crankshaft pinion and the compensating gear. (See Figure 80.)

Figure 81 will serve to further illustrate the gear

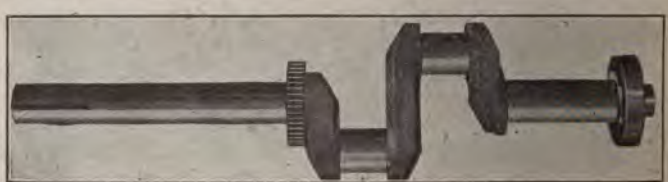


FIGURE 78.
Crankshaft on 20-35 H.P. Tractor.

connections and principal working parts of this tractor. Neither cooling fan nor water pump are used on the engine; the exhaust, it is claimed, draws sufficient cool

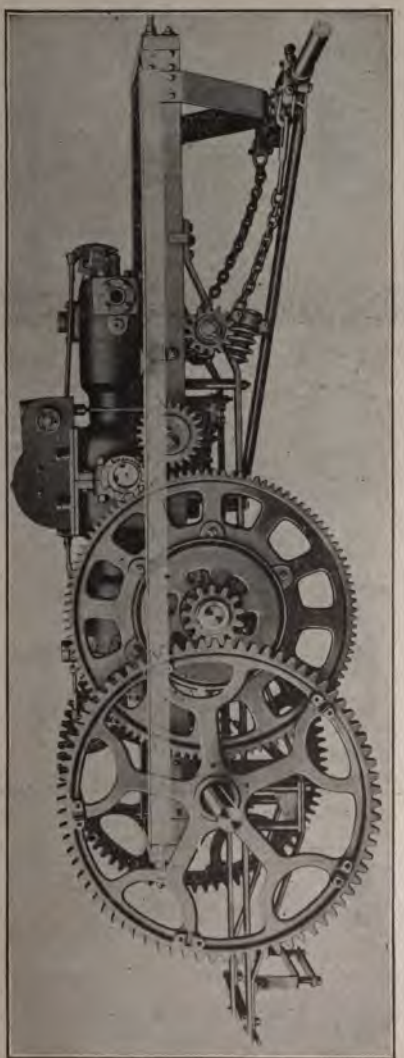


FIGURE 79.
Side View of Avery 20 H.P. Tractor Frame, Gearing and Motor.

air past the tubes for cooling purposes. The entire power plant is mounted on a sliding frame, to which reference has already been made.

Governor.—The speed of the Avery tractor is controlled by the Pickering governor. A 2-in. governor is used on the 12 and 20 h.p. sizes, and a 2½-in. on

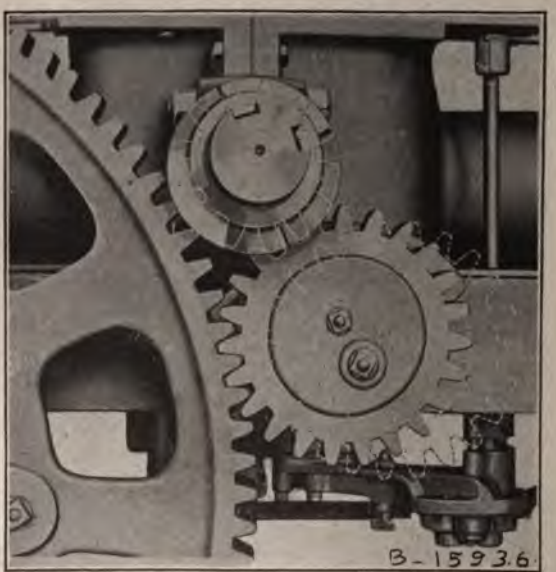


FIGURE 80.
Phantom View of Intermediate Gear, Showing Various Positions.

the 40 h. p. The governor is placed in the manifold between the carbureter and the cylinders. If differs only from steam in one respect that the mixture passes through the governor in the opposite direction. This governor gives a steady motion to the motor with very little variation in speed. The valves are located in the

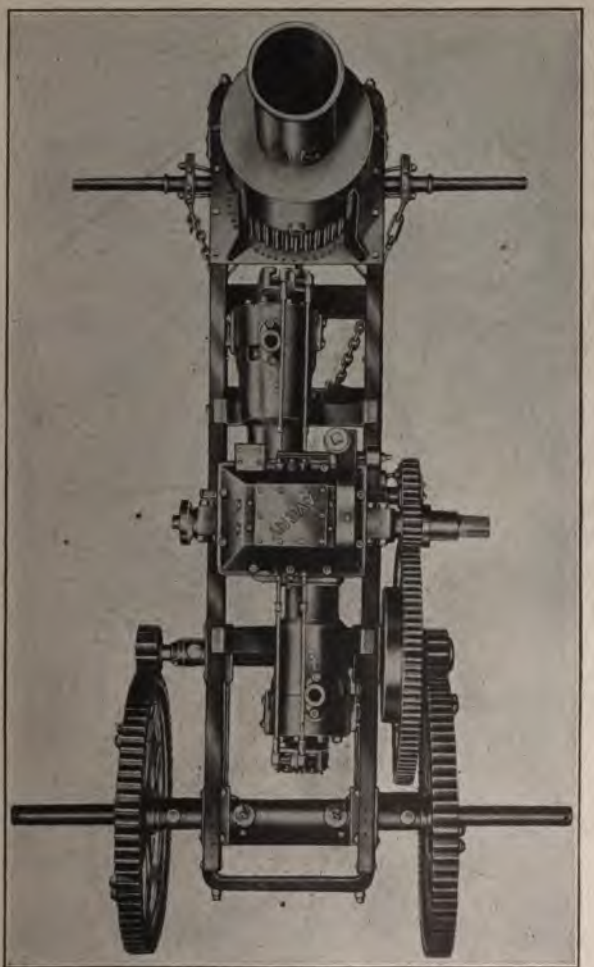


FIGURE 81.
Top View of the Avery 20 H.P. "Light-Weight" Tractor, Showing All of the Principal Working Parts—the Motor and All of the Gearing.

head, thus doing away with all valve pockets and chambers. The valve gear and cams are housed in one casing which is located directly over the crankshaft and can be removed quickly. The cylinder heads are removable, the cooling water, however, does not pass direct from the cylinder jacket to the water head through the packing, but through a U-pipe, and no water can therefore get into the inside of the cylinder.

The radiator is round and made of vertical tubes, thus permitting the air to strike the radiator, no matter from what direction it is blowing.

Lubrication.—A positive oiling system operated by a gear pump is employed. The surplus supply of oil is contained in an oil reservoir and is pumped up and forced on the bearings under pressure, which insures its going to the spot and doing its work.

The engine is equipped with a dual ignition system, both batteries and magneto.

Clutch.—Figure 82 shows a view of the combined clutch and belt wheel brake, which serves whether the tractor is traveling forward or backward or driving in the belt. This clutch has three clutch arms, on the ends of which are three large wood shoes. It has a good grip on the belt wheel and yet will release easily. The belt wheel does not travel with the motor unless the clutch is engaged. This makes it possible to put the belt on the flywheel and back into it by slipping the clutch much more easily than it is possible when the belt wheel is fast to the shaft and revolves at the motor speed. Furthermore, the same lever which throws the clutch in, when drawn back, engages a brake on the outer surface of the belt wheel, by which it can be stopped almost instantly for engaging the gears or should

any accident happen to the separator, sheller, saw, or other machinery which is being driven.

Shafting.—The crankshaft is made from forged steel. The countershaft is cold rolled steel, and revolves in a solid babbitted bearing. Both the countershaft and rear

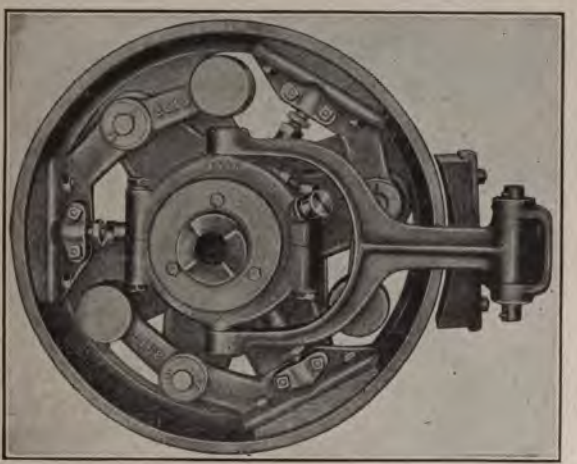


FIGURE 82.
Clutch and Belt Wheel Brake.

axle boxes have large oil wells in the center for oiling the bearings.

Fuel Tank.—Each tractor is equipped with a square steel fuel tank located on the left hand side of the frame directly above the rear axle. The total fuel capacity of the tank is as follows: 12 h. p., 32 gals.; 20 h. p., 42 gals.; 40 h. p., 67 gals.

Various Equipments.—A plow hitch is furnished regularly with Avery tractors. It is located directly under the rear axle so that, in turning, the draft of the plows does not interfere with the steering. Each tractor is

also equipped with an automatic coupler for coupling on wagons or other machinery. The platform is steel and mounted on springs which take the jar of traveling off the operator. A strong foot brake is provided which operates a steel band around the compensating gear shell. A cab is furnished regularly with these tractors as shown in illustrations. A gravity gear oiler is furnished regularly for oiling the gearing and shafting.

TWIN CITY GAS TRACTOR.

The Twin City gas tractor, built by the Minneapolis Steel and Machinery Co., is manufactured in two sizes, 25 and 40 h.p. Figure 83 shows a view of the larger size. A side sectional elevation is given in Figure 84, and a cross section of one of the cylinders, showing the piston, valves, connecting rod and spur gear is shown in Figure 85. The motor is of the four-cylinder, four-cycle type; bore, 7¼ inches, stroke, 9 inches. Each cylinder is cast separately with head, cylinder body and valve chambers all in one solid piece. This method of construction dispenses with all studs, bolts and packed joints, thus removing a source of trouble. Figure 86 is a sectional view of a cylinder casting, and shows the one piece construction. The water jacket enclosing the cylinder is also shown in the cut.

Valves.—The valves are nickel steel forgings, ground to their seats, and they are also well surrounded with water jackets. They may be easily removed by unscrewing the caps over the valve chambers and lifting the valves out of their seats. The valves are interchangeable.

Governor.—The governor is of the fly ball type, and is housed in an oil-tight dust-proof brass case. It is geared directly from the camshaft and controls the speed of the engine within a few revolutions from full load to no load by regulating the fuel supply. The governor and controlling device are shown to the left of Figure 84.

Camshaft.—The camshaft positively operates both the intake and exhaust valves through a single tappet, the

FIGURE 83.
The Twin City "40."

whole being completely housed in the crankshaft case directly under the valve chambers. The cams are of a special grade of tool steel, hardened and ground. They are keyed and pinned on the camshaft. The cam gears are cut from solid steel forgings and are hardened. The boxes in which the camshaft revolves are so designed

that after removing the cover plates they may be taken out or adjusted without disturbing any other part of the motor.

Ignition.—The ignition system is provided with a high tension magneto of standard make positively driven direct from the camshaft gear, which insures perfect timing and the distribution of current to all the cylinders.

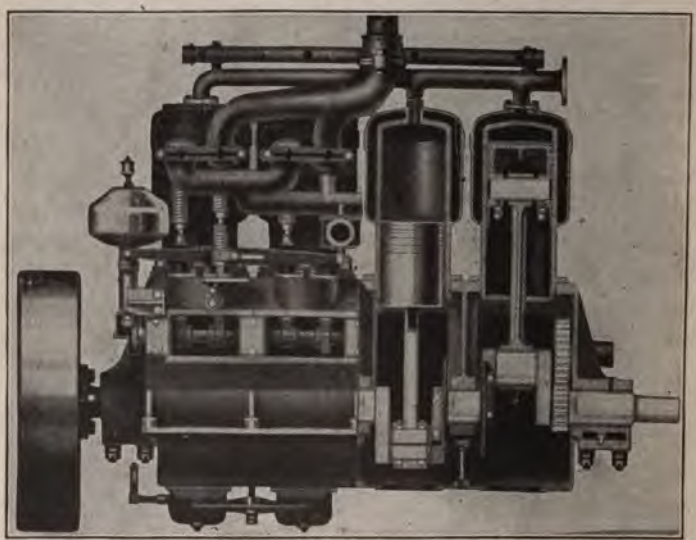


FIGURE 84.
Twin City "40" Motor, Side Sectional Elevation.

Lubrication.—The cylinders and crank bearings of the motor are lubricated by a multiple force feed system, the oil being pumped by a positively driven force pump through individual pipes directly to the cylinders and bearings. Gears and all other parts are lubricated from the main oil reservoir, the oil being carried to the bear-

ings and gears by a separate pipe provided with a special lubricating valve.

Connecting Rod.—The connecting rod is a nickel steel forging with an interchangeable hard bronze bushing at

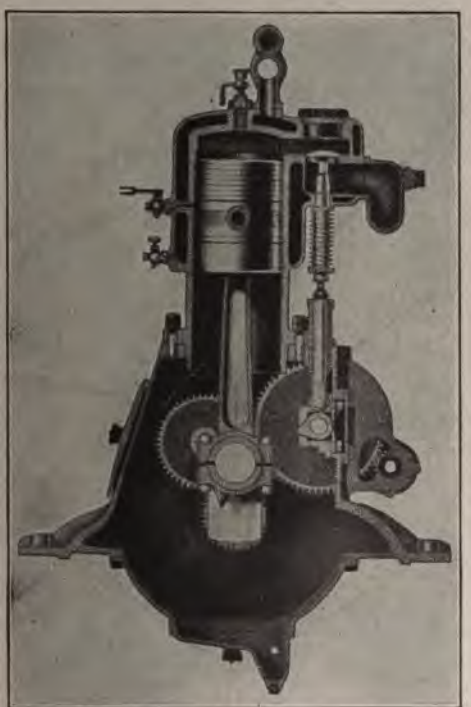


FIGURE 85.
Twin City "40" Motor, End Sectional Elevation.

the piston end, and with Parson's interchangeable bushings in the crank bearing. The cap is secured to the rod by nickel steel bolts provided with slotted nuts and cotter pins, which prevent the nuts from coming loose.

Pistons.—The surface of pistons, piston rings and pins are finished with a water grinding machine which will finish these parts to one-thousandth of an inch. A piston can easily be removed through the side of the crank-case without disturbing any other part of the motor. Figure 87 shows the construction of the connecting rod, piston and cylinder.

FIGURE 86.
Section of Cylinder.

Crankshaft.—The crankshaft, Figure 88, is a single forging of high grade steel. It has five bearings, made of Parson's white bronze bearing metal. Each bearing is oiled by an individual oil pipe leading from the force-feed oil pump and the crank pins are also lubricated through individual pipes from the same oil pump.

The flange of the crankshaft is forged solid with the crankshaft and to this flange the flywheel is bolted.

Figure 89 shows a view of the crankshaft as it appears when looking up from beneath the crankcase.

Transmission.—The main transmission operated by an expanding clutch in the flywheel is assembled complete in a single steel casting as shown in the illustration, Figure 90, and is then bolted to the top of the frame back of the motor and directly over the rear axle.

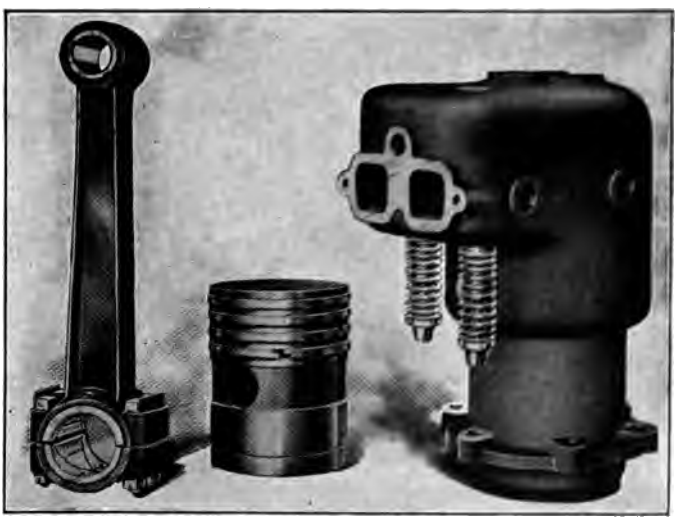


FIGURE 87.
Connecting Rod, Piston and Cylinder.

Belt Wheel.—The belt wheel is operated from a pinion on the front end of the motor, entirely independent of the gearing which propels the tractor. By this arrangement the main transmission is relieved of all wear when the belt pulley only is running. The forward gears are thrown completely out of mesh when not in use. A

brake operates on the pulley to stop its spinning as soon as the clutch is thrown out.

Bevel Gear.—The bevel gears are cut from spherical

FIGURE 88.
The Crankshaft.

sections of high grade steel, see Figure 91. This system of cutting gears produces the most efficient tractor transmission known, and effectually answers all arguments

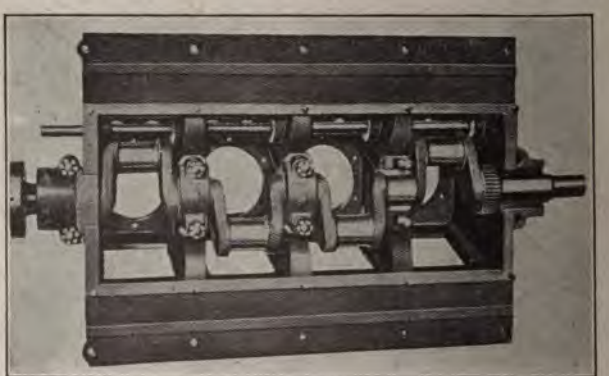


FIGURE 89.

against the efficiency or durability of bevel gears. The main pinion of this tractor is geared directly into the differential, thus dispensing with an intermediate gear (Figure 92). The centers of the respective shafts are

arranged in the three points of a triangle, thus making the shortest possible distance to carry the power, besides being a compact and rigid construction.

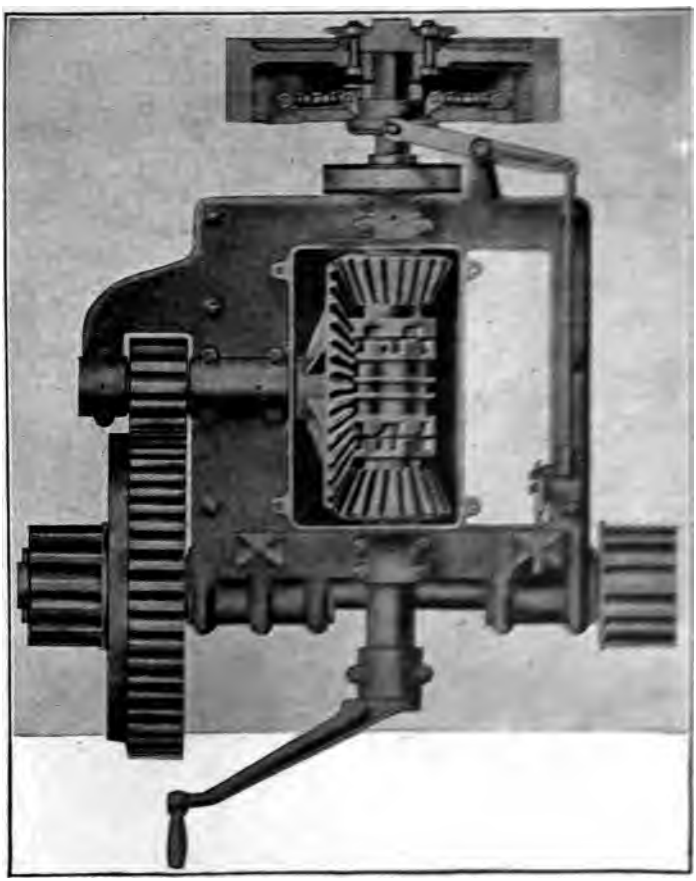


FIGURE 90.
Showing Main Transmission Complete from the Clutch in the Engine Flywheel to the Bull Pinions.

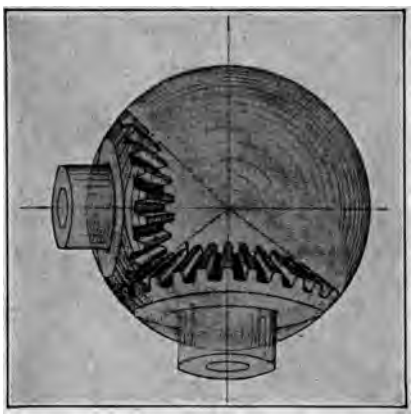


FIGURE 91.
Gears Cut in Spherical Sections.

Master Gear Adjuster.—The rear axle is equipped with an adjusting device, (See Figure 93), by means of which the axle bearing may be moved to take up any wear which may occur in the master gear or pinion and

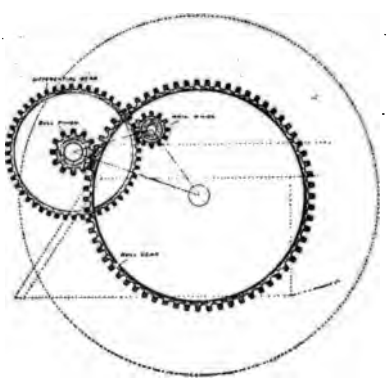


FIGURE 92.
Showing System of Gearing.

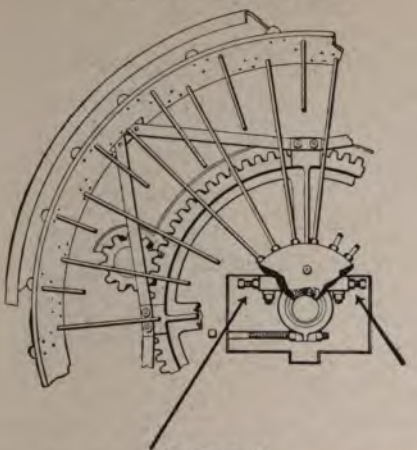


FIGURE 93.
Showing Method of Adjusting Rear Axle.

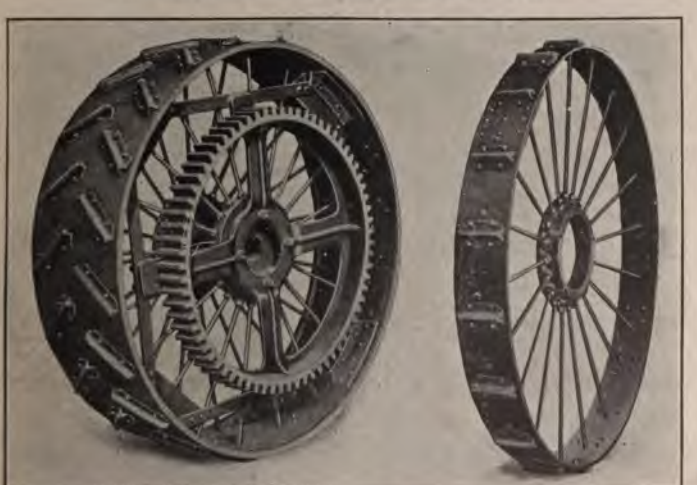


FIGURE 94.
Rear Wheel Showing the Bull Gear and Tension Bars Which Carry All the Driving Force to the Wheel Rim.

12-inch Rear Wheel Extension Equipped with Cleats.

also renders possible the use of another size of pinion in case it is desired to change the speed of the tractor.

Wheels.—The rear wheels on the 40 h. p. tractor are 84 inches in diameter and have a 24-inch face. An extension is furnished which will widen the face to 36 inches. Figure 94 shows the rear wheel and also the extension to be attached when necessary.

Drawbar.—The drawbar is attached to one of the forward cross braces of the frame by a powerful elastic spring suspension. To the drawbar is fastened the detachable plow hitch.

Cooling System.—The cooling system is of the forced circulation type, using an enclosed radiator from which there is no water consumed through direct evaporation. Consequently one filling of the radiator will last indefinitely, barring leaks. Circulation is maintained by a centrifugal pump driven from the crankshaft. A large fan operated from the same source draws the cooling air through the 185 tubes in the radiator.

SAWYER-MASSEY GASOLINE TRACTOR.

A view of this tractor is shown in Figure 95. It is built by the Sawyer-Massey Co., of Hamilton, Canada. It is manufactured in two sizes, 25 and 45 h.p., and the general dimensions are as follows: height, 124 ins.; width, 108 ins.; length, 190 ins.; wheel base, 125 ins.; cross shaft, 3⅛ ins.; compensating shaft, 3¼ ins.; intermediate gear shaft, 3⅛ ins.; pump shaft, 1¼ ins.

Motor.—The motor (See Figure 96) is of the four-cylinder, four-cycle vertical type, water cooled. The four cylinders give a frequency of impulse which is absent from the single and two-cylinder engines, thus

giving a continuous flow of power to the gearing and lessening strains and torsional stresses.

Crankcase.—The enclosed crankcase is dust-proof and provided with hand-hole openings for inspection. The lower half of the crankcase constitutes an oil pan.

FIGURE 95.

Sawyer-Massey Gasoline Tractor—Right View 25-45 Horse Power.

Access to the connecting rod bearings is through removable plates in the bottom of the crankcase. The lubricating system is so arranged that the oil in the crankcase remains at a constant level.

Crankshaft.—The crankshaft, Figure 97, is drop forged from high carbon steel and is provided with interchangeable die cast babbitted bearings. These bearings, of which there are five, are 2⅝ ins. in diameter, one on each side of each crank, the total bearing surface

being 20½ ins. The crank bearings are 2¾ ins. in diameter and 3½ ins. long.

Pistons.—The pistons (See Figure 98) are 9 ins. in length and are fitted with four expanding rings with

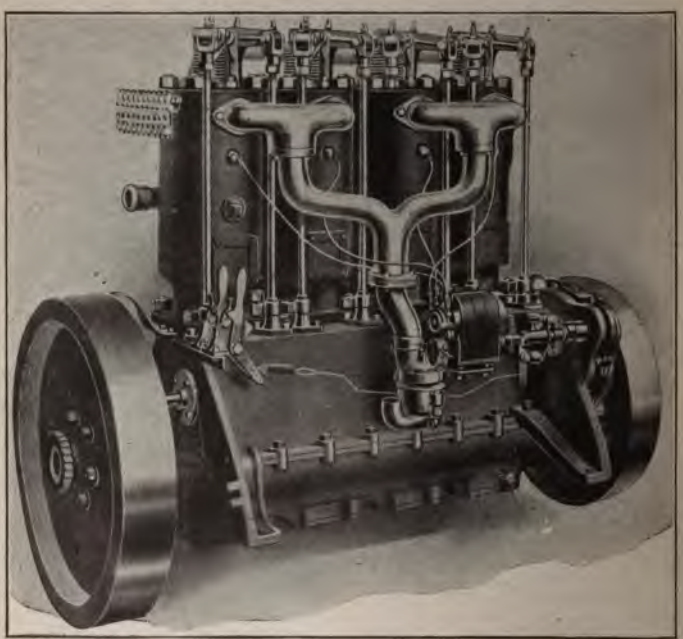


FIGURE 96.
Showing Intake Side with Carbureter and Magneto.

butt joints. Each ring is fastened to the piston with a pin in order to prevent its turning. An added feature is the provision of an oil groove just below the bottom ring which scrapes off the extra oil and allows it to the piston pin bearings. Two extra oil grooves are pro-

vided at the bottom end of the piston to help keep the oil from getting into the combustion chamber. The piston is carefully machined and ground to exact measurements.

FIGURE 97.

Sawyer-Massey Gasoline Tractor Crankshaft.

Piston Pins.—The piston pins are of generous size, being 1⅝ ins. in diameter, made of steel, case hardened and ground. They are provided with bronze bushings in the piston, which can be renewed when required.

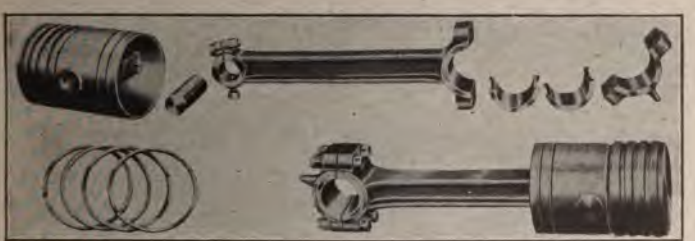


FIGURE 98.

Sawyer-Massey Gasoline Tractor Piston, Also Showing Piston, Rings, Pin, Connecting Rod and Cap with Die Cast Babbitted Bearings Before Assembling.

Clutch.—The clutch (See Figure 99) is of the expanding shoe type, is self-locking, and is provided with friction shoes of hard maple which can be easily replaced.

Bevel Gear Case.—This is cast in two pieces and has a hand-hole for inspection purposes, covered with a plate, which can be quickly removed. The bevels are

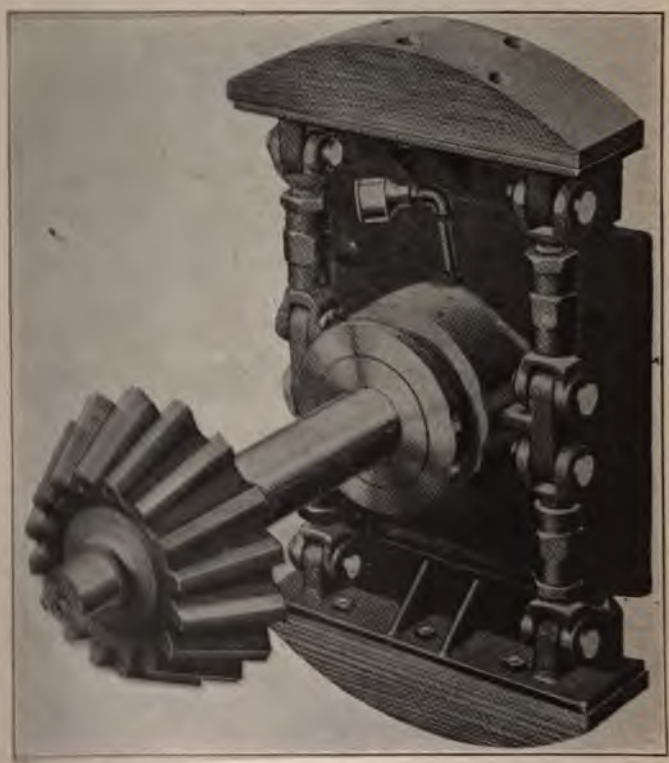


FIGURE 99.
Sawyer-Massey Gasoline Tractor Clutch Complete with Shaft and Bevel Pinion.

free on the pulley shaft. The pinion runs between the two bevels, and to reverse, a dog clutch is used which [illegible]etween the two bevels into one of the other

gears. The shafts of the gear case are provided with four double row annular ball bearings, which take both radial and thrust loads. These bearings prevent any side motion, and are very much superior to the babbitted bearings, as they ensure that the bevel gears will always remain correctly aligned. The bevel gears are made of steel with machine cut teeth. The case is dust proof, and the gears run in a bath of oil which ensures minimum wear on the parts and helps to transmit the power with the least possible friction loss.

Speed.—This tractor has two speeds, one of 2 miles and the other of 3½ miles when the motor is running 600 revolutions per minute.

Gears.—The train gears are placed inside the frame and have 4-in. face and 1¾-in. pitch. The low speed pinion is cast steel. The intermediate gear has a bronze bushing 10 ins. long. The traction wheel gears are 5-in. face and 2½-in. pitch. All pinions are cast steel. The bull pinions are supported by a frame bearing close up to the gear.

Compensating Gear.—The compensating gear is of the four pinion type, lubricated by a compression grease cup at the end of the shaft. The rim is separate and is bolted to the center casting that carries the bevel pinions. In case the gear should need replacement through the breaking of a tooth, all that is necessary is the replacement of the rim.

Cylinders.—The cylinders, Figure 100, are made of the best grade of grey iron, cast separately with removable heads. Any cylinder can be removed without interfering with others. The water jacket completely surrounds the cylinder and is provided with a removable cover for cleaning. The cylinder heads are separate and

are secured to the cylinders by heavy studs, four to each head. They contain the valves and are easily removed for the purpose of grinding valves or cleaning the combustion chamber.

Valves.—The valves are water-jacketed. They are of the poppet type, made of nickel steel, ground and fitted

FIGURE 100.

Sawyer-Massey Gasoline Tractor Cylinder, Showing Right and Left Sides with Part Cut Away to Give View of Auxiliary Exhaust Ports. Also Cylinder Heads, Valve Springs, Cap and Nut.

after being heat-treated. The valves are mechanically operated by overhead rockers and push rods.

Cams and Camshaft.—The camshaft is 1⅛ ins. in diameter and is made in one piece with five individual bronze bearings. It is so constructed that it may be removed by sliding endways from the crankcase. The cams are all hardened and ground and secured to the shaft by a key and two taper pins. Machine cut spur gears of steel are used for camshaft gearing.

Ignition.—The ignition system consists of a Remy high

tension magneto in conjunction with a six-cell dry battery for starting. The magneto is covered with a dust and water proof cover, thus preventing short circuits.

Carbureter.—The carbureter is of the floating ball type, having no spring adjustments to make, and only one regulation to adjust the amount of gasoline. It is automatic in its control of the mixture for light and heavy loads.

Governor.—The governor is of the centrifugal ball type, which operates the carbureter and regulates the speed of the engine both on the air and the fuel supply. It is positive in its action. The speed can be varied 300 to 600 revolutions per minute, and if the load is suddenly released the governor takes care of the engine instantly by at once cutting down the supply of fuel and air, and thus prevents racing.

Connecting Rods.—These are of I beam type, 18 inches between centres with bearings on crankshaft $2\frac{3}{4} \times 3\frac{1}{2}$. All connecting rod bearings are die cast and are adjustable. The lower half of each connecting rod bearing has an oil dasher which splashes the oil on the bearings requiring it. Figure 98 shows the construction of the connecting rod and its bearings.

Lubrication.—The lubrication of all bearings is accomplished by means of a gear oil pump which is driven from the camshaft by a noiseless roller chain and draws its oil from a tank through a filter and pumps it into a 10-unit sight feed oiler, which has oil tubes running to crankshaft bearings, magneto gears, and cylinders.

Cooling System.—The cooling system consumes very little water. There are 252 $\frac{5}{8}$-in. seamless brass tubes, 32 ins. long, used in the form of a radiator and a large centrifugal pump circulates the water around the cylin-

ders and through the radiator. It takes but 30 gallons of water to fill the whole system. The radiator is cooled with a 30-in. fan at its back, driven by a belt from pump shaft.

MINNEAPOLIS FARM MOTOR.

This motor, Figure 101, is of the four-cylinder, four-cycle type, and the cylinders, instead of being in a vertical position, are located parallel with the frame

FIGURE 101.
Left Hand View—The Minneapolis 40 H.P., 4-Cylinder (Horizontal) Farm Motor.

and lie horizontal. The cylinders are 7¼ inches in diameter by 9-inch stroke and are cast in pairs, as will be seen by a glance at Figure 102. Cylinders and com-

bustion chamber are cast together, thus dispensing with packed joints between cylinders and heads. The whole is secured to the motor base or crankcase by large heavy bolts, and the motor base is in turn securely bolted to the frame.

Frame.—The frame is stiff and rigid, being constructed of steel I beams reinforced by angle steel, thus giving

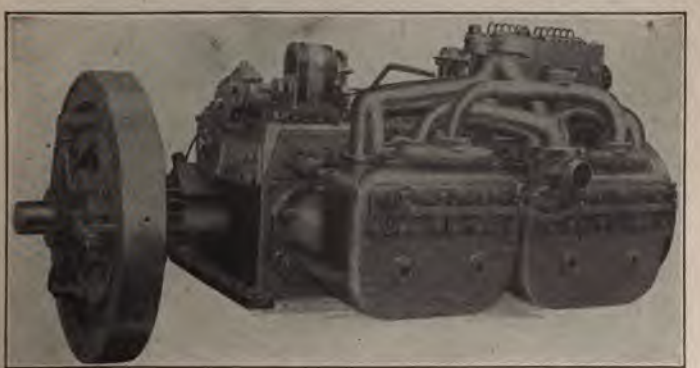


FIGURE 102.
View of 40 H.P. Motor.

maximum strength with minimum weight. A skeleton view of the frame, steel gears and shafting is shown in Figure 103.

Valves.—The valves and valve stems are of nickel steel in one piece, turned and ground to size. Water space surrounds the valves, keeping them at a uniform temperature, thus reducing the chance of warping or breaking. Cast plates located in the heads of combustion chambers can be removed to gain access to valves for grinding or cleaning.

Pistons.—The pistons are cast from the same quality of grey iron as are the cylinders. Each piston is fitted with four cast rings, carefully machined, ground and fitted.

Camshaft and Cams.—One camshaft with cams operates the intake and exhaust valves. The cams, rollers and pins are of ample dimensions.

Connecting Rods.—The connecting rods are made from forged steel and are of large dimensions. The bearing

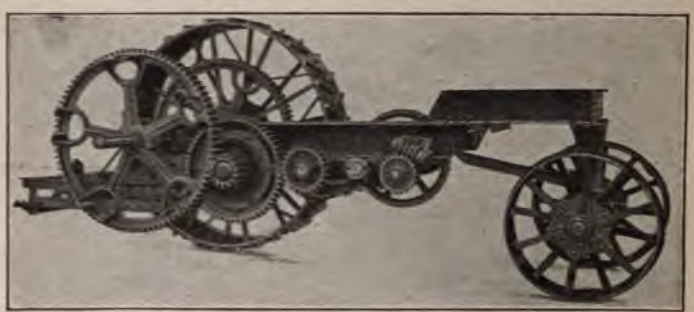


FIGURE 103.
Frame, Steel Gears and Shafting, Minneapolis 40 H.P. Motor.

at the cross head end is an inserted brass bushing. The crank pin bearing is made of white metal, 3½ by 3¾ ins. The caps at crank end are skimmed for taking up wear. They are secured by four bolts, double nutted and pinned.

Gears.—All transmission and traction gears are steel, of large dimensions to insure great strength and durability.

In designing and constructing farm motors for the heavy work required of them in plowing, hauling, etc.,

the traction gears and parts are most important features. There are two speeds forward and one reverse, controlled by a single lever. The gear oiler works automatically and regulates the amount of oil to be used.

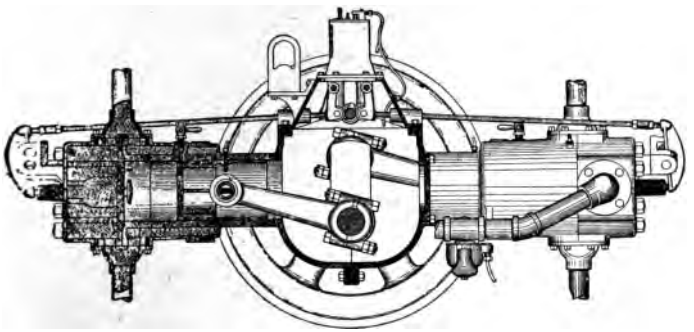


FIGURE 104.

Sectional View of Minneapolis Universal Double-Opposed Motor. One Cylinder is Shown as if Cut Through the Center Lengthwise, the Better to Illustrate the Piston, Valve, Waterspace, Etc.

Ignition.—Double system jump spark. Two spark plugs in each cylinder, wired to a Remy high tension magneto, gear driven, and to a set of dry cell batteries for starting and emergencies.

Lubrication.—Multiple feed oil pump, chain driven, located in plain view of operator, enabling him at all times to see and regulate the amount of oil mechanically forced through individual tubes to motor bearings, cylinders and other parts. Splash system in crankcase is also used, thus giving two distinct systems of lubrication.

Cooling System.—Positive circulation by means of a large gear driven pump. Radiator holds 50 gallons and

consists of a top and bottom water tank, connected by a series of long brass tubes, cooled by a large fan.

The builders of the 40 h. p. motor, the Minneapolis Threshing Machine Co., also build a smaller size, 20 h. p., which they call the "universal double opposed" motor. A good idea of the construction and action of this motor may be obtained by an examination of Figure 104. It will be seen that there are two cylinders, lying horizontal and facing each other, and both apply power to the same crankshaft. The details of construction are similar to those of the 40 h. p. motor, with the exception that the 20 h. p. motor has but two cylinders, located on opposite sides of the crankshaft, while the larger size motor has four cylinders lying parallel with each other and all on the same side of the shaft.

CASE GASOLINE TRACTORS.

Figure 105 shows a view of the 40 h. p. tractor manufactured by the J. I. Case Threshing Machine Company, Racine, Wis. The motor is of the two-cylinder opposed type, as shown in Figure 106, which is a plan view of the mounting of this tractor. The following brief description will cover the principal features of the machine:

Motor.—Two-cylinder horizontal opposed; size of cylinders, 7¾-in. bore x 8-in. stroke.

Rating.—Brake horse power, 40; draw-bar horse power, 20. Normal engine speed 450 revolutions per minute.

Road Speed.—Two forward speeds, 2 and 2¾ miles per hour. The first speed is used for plowing, and the second for hauling or other road work. Reverse speed is the same as the plowing speed.

Rear Wheels.—Diameter [illegible] in., face [illegible] in., thickness of tire [illegible] in. [illegible] extension tires furnished as [illegible].

Front Wheels.—Diameter [illegible] in., face [illegible] in.

Transmission.—Drive is direct from crankshaft to the differential gear at both forward speeds. Differential shaft is geared to both the main road wheels. No idle

FIGURE 105
Case 40 Gas Tractor.

gear is in mesh except when reversing. This is also true when engine is used for belt work.

Gears.—All gears are of semi- or cast steel. The master gears and pinions have 4½ in. face and 2 in. circular pitch. Differential gear is spring mounted.

Shafting.—The rear axle is 3 15/16 in. diameter, running in a cannon bearing extending the entire width of the tractor. Differential shaft is 2 15/16 in. diameter, supported by three bearings, two of which are placed each side of the main differential gear.

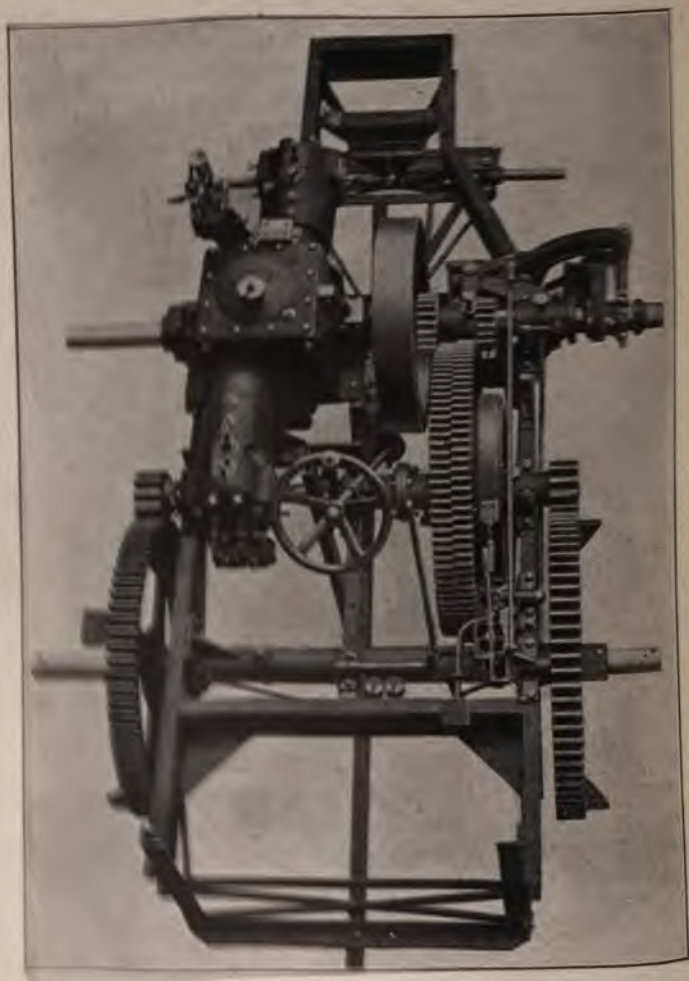


FIGURE 106.

Mounting of Motor Transmission.

gnition.—Is of the high tension type. Batteries are
d for starting only. A high grade magneto is pro-
ed, driven direct from the engine.

Governor.—This is of the fly ball type connected direct
governor valve. Regulation is on the throttle principle.
valve, hand controlled from operating platform, is
vided so that engine speed can be reduced when nec-
ary to run engine idle.

Lubrication.—Engine is provided with a geared pump
ing the oil from bottom of crankcase and supplying
o all the engine main bearings.

Weight.—Total weight approximating [illegible] lbs.
eight on rear wheels, [illegible] lbs. Weight on front
eels, 4,000 lbs. Capacity of fuel tank, [illegible] gallons.

The Cylinder.—Cylinder heads, valve seats and valve
ns are thoroughly water jacketed. The valves are
de with nickel steel heads fused on to carbon steel
ns, and accurately ground to size.

Oiling System.—Force feed lubrication is used to oil
different parts of the engine. The pump is positively
ven. It is of the gear type, and is located so that oil
vs into it from the lower part of the crankcase. From
discharge side of pump the oil is fed, so that it
roughly lubricates running parts of motor.

Thermo-Syphon Cooling System.—The radiator used
his cooling system is of the closed type, and is so con-
ucted that it can be readily cleaned from deposits
ch may take place from the water.

The main driving pinions (See Figure 10[illegible]) are placed
e to the bearings, doing away with any overhang, and
will be seen that the drive pinions on the crankshaft
supported not only by the engine bearing but are
vided with an extra outboard bearing. By this con-

struction the overhanging strain on engine main bearing due to belt pull is completely eliminated.

The differential shaft has three bearings, two placed close to the main differential gear, which prevents undue deflection of shaft and adds bearing surface at the point of greatest strain.

Brake.—A substantial brake is provided, acting directly upon the differential gear. This has a lock which is used very advantageously when engine is used on the

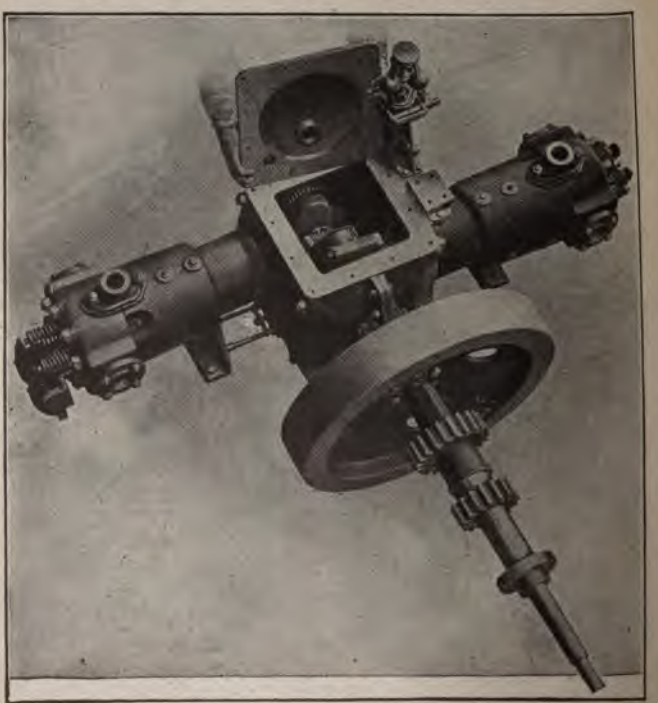


FIGURE 107.

Inside Crankcase and Flywheel.

belt, doing away with the necessity of blocking. Figure 106 also shows the location of lever for operating clutch and the position of the hand wheel for steering.

The brake shoes have very large bearing surfaces and are lined with asbestos brake lining, a material which has high frictional resistance and will not wear or burn out readily when the clutch is allowed to slip. Connected to same lever which operates clutch is a powerful brake which is applied directly to the outside of belt pulley.

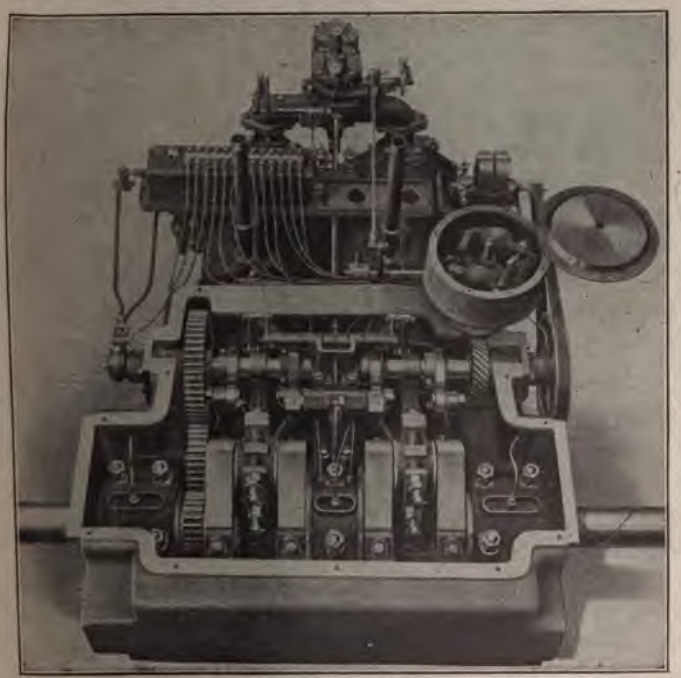


FIGURE 108.
Plan View of 60 H.P. Motor.

This can be used to stop immediately the rotation of pulley when used for belt work, or when transmission gears are in mesh. It is of sufficient power to hold the tractor on the steepest incline. It will be seen from the illustration (Figure 107) that the inside of the crankcase is made accessible simply by removing a cover plate, to which no operating parts are attached.

The J. I. Case Co. also manufacture a 60 h.p. gas and oil tractor designed for heavy work. Two cylinders are used on this size motor also, but instead of being opposed, as on the 40 h. p. tractor, the cylinders are

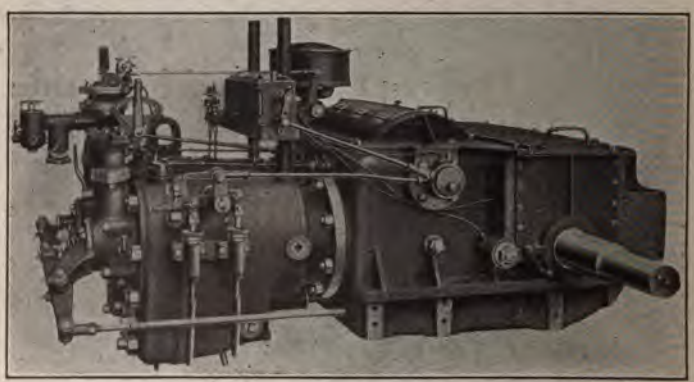


FIGURE 109.
Left Side of 60 H.P. Motor.

both on the same side of the crankshaft, as will be seen by an inspection of Figure 108, which shows a plan view of the motor with the crankcase cover removed. The crank pins are set 360 degrees apart, so that a power impulse is received every revolution, which is not the case with two-cylinder engines of the same type having their crank pins 180 degrees apart. The speed of this

motor is 350 r. p. m. Figure 109 is a side view showing the design of the case, also the oil and fuel pumps and various other equipments.

Crankshaft.—Figure 110 shows the crankshaft, also the flywheel, clutch and pinion for operating transmission. The belt pulley is also shown. This pulley is operated by a separate clutch, entirely independent of that used for transmission.

It is possible with this arrangement when operating on the belt to tighten the same without in any way interfering with the load. To do this all that is necessary is

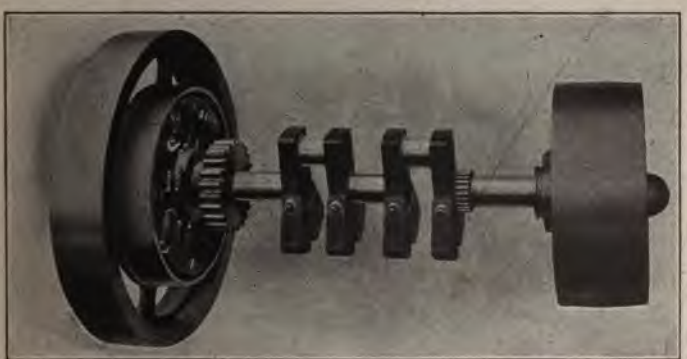


FIGURE 110.
Crankshaft 60 H.P. Motor.

to place the gears in reverse position and tighten up on transmission clutch. The rotation of belt pulley is such that a crossed belt is used for operating threshing machines.

Oiling System.—A positive driven force-feed lubricator, so located that the feeds can be observed from the

engineer's platform, supplies the necessary oil for lubricating all the principal engine bearings.

Main and crank-pin bearings are of the removable shell type. They are lined with high grade babbitt, which when worn can be quickly replaced without it being necessary to dismantle any part of engine.

All parts, such as ignitor plugs and valve cages, are provided with ground iron to iron seats, which makes the cooling of these parts more efficient, and also does away with troublesome gaskets.

Ignition.—For furnishing current for starting, dry batteries are supplied, and a magneto after engine has been brought up to speed. The ignition system is so arranged that the time at which the spark takes place can be changed while the engine is in operation, and the magneto is protected from the weather by a sheet of metal cover.

Transmission.—Next in importance to the engine is the transmission. It is of the utmost importance that the transmission shafts be held in perfect alignment. If this is not done, transmission gears will show wear, and breakages in a very short time. The cannon bearing for the rear axle is machined and fits into a saddle pad, which is a part of transmission housing.

Careful attention has been given to the selection of right material for the various parts composing this tractor.

The crankshaft is made of .35 carbon steel which is forged from a single billet and accurately ground to size, both in the bearings and crank pins.

The connecting rods are drop forged of I section and carefully heat treated.

The cylinders and pistons are made of a special mixture of close-grained cast iron.

All gears used on the transmission are semi-steel.

Carbureter.—Its construction is such that it will use either gasoline, naphtha, distillate or kerosene without change.

Cooling System.—No fans are used, the necessary draught being created by utilizing the exhaust pressure.

PART II.

PART II.

CHAPTER I.

WATER SUPPLY SYSTEMS IN THE FARM HOME.

By S. E. Brown.

One of the causes of dissatisfaction with farm life is the lack of conveniences in the home. It must be admitted that when compared with the conveniences found in the average city dwelling, the farm home even of the well-to-do farmer shows badly. Labor saving devices have been purchased for farm use to a very great extent. The money invested for conveniences for the home, however, is comparatively small. Fortunately, this state of affairs is changing, and while a few years ago one would possibly have found a sewing machine, washing machine, bread mixer and perhaps a few other articles whose use lightened the labors of the housewife, it is now not uncommon to find in addition to the above mentioned articles, water systems, heating systems, lighting plants, refrigerators, vacuum cleaners, fireless cookers, etc.

There can scarcely be any dissention to the statement that of all the above mentioned items, the water system

stands first in its importance to family comfort and welfare. The farmhouse with a pressure water system has all the advantages and sanitary conveniences of the city home. A modern bathroom, kitchen, sink, hot water tank, running water in the laundry, dairy and barn are comforts and conveniences of far greater value to the farmer than the small cost they represent.

One great virtue of a pressure water system is that it makes a modern bathroom possible. From a hygienic standpoint the bathroom is an absolute necessity. The conditions under which the average family on the farm lived until recently, would not be tolerated by a city family. Of course, one can have baths regardless of whether there is a water pressure system or not. But the plain fact is that bathing is neglected when it means the carrying of water from well or cistern, heating it on the stove, and securing, after all this effort, a rather unsatisfactory bath. When a man comes in from the field after a hard day's toil, his body reeking with perspiration, dusty, tired, exhausted, nothing is more refreshing and conducive to a good night's rest than a pleasant, agreeable bath. It will be taken, too, when the only effort required is to turn on the water.

When the element of convenience is considered it is surprising that the farmer has so long permitted himself—and especially the women of his household—to worry along with the endless toil of water pumping and carrying. It is the wife and daughters that usually suffer most. Not only must water be carried for ordinary domestic purposes, but on wash days, when the work should be lightened, it is increased by the labor necessary to carry tubful after tubful from cistern or well, frequently in inclement weather when the risks from exposure are

great. Contrast this with running water, both hot and cold, always on tap. The sum that would be invested in a new implement to lessen the work on the farm should surely not be considered exorbitant to expend for equipment that will put an end to all this needless drudgery.

Water systems as now offered for private installation give ample opportunity for one to secure apparatus that is dependable and that can be secured for a reasonable outlay. One of the most popular types marketed is known as the Fresh Water System, so called because with it water is delivered "fresh" from the well to the faucet. This system will always have preference where convenience and flexibility are given first consideration. It is, in fact, the most modern method of water delivery under pressure and gives service fully equal to, and in most cases surpassing, that available in the city. For instance, it is not at all infrequent to find these systems supplying water from well or spring for drinking purposes; from a cistern for domestic use; and from one or more additional wells for stock and general purposes, and all operated by only one power plant. This Fresh Water System is available when the water does not have to be elevated more than 100 feet and where the water is clean, free from sand, grit and other impurities.

These plants consist of an air compressor which may be driven by a small gasoline engine, or electric motor, an air-tight steel tank for air storage and an auto-pneumatic pump for each source of water supply. These pumps consist of two small metallic chambers which are submerged in the water. When a faucet is opened they automatically fill and discharge due to the compressed air pressure from the storage tank, thus giving a continuous flow of water. In addition to the strong feature of

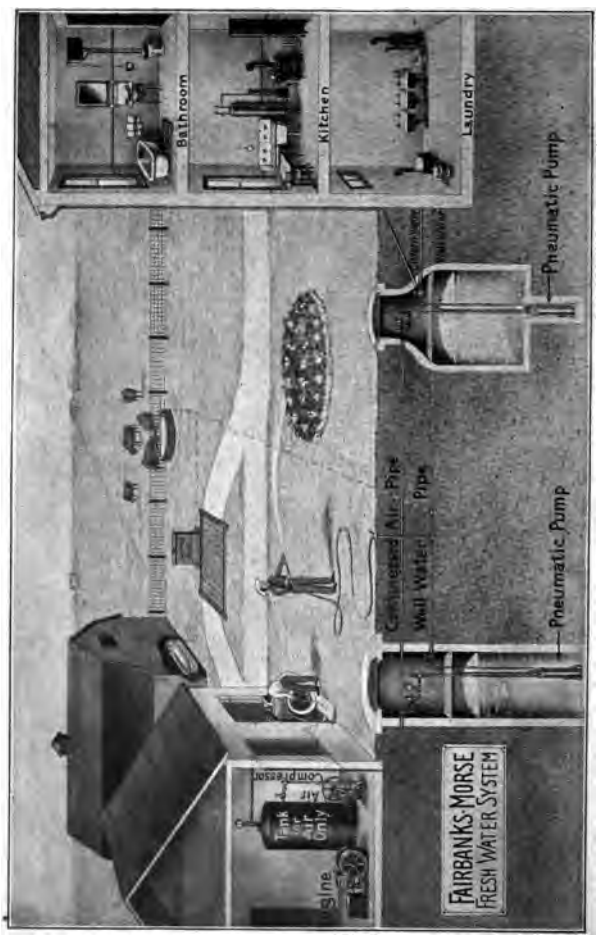


FIGURE 1.
Fresh Water System Operated by Gasoline Engine or Electric Motor.

water being delivered fresh and cool an advantage of this system is that since compressed air can be piped most any distance to the auto-pneumatic pump in the well without any appreciable loss, the power plant, and air storage tank can be located wherever convenient, as in barn, garage or dry basement. This makes it an easy matter, where an engine is used, to arrange to have it drive other machinery when not in use for pumping water.

For the benefit of our readers who may be interested to know something of the engineering problem in connection with water systems we give below a table showing the amount of water, in gallons, that can be drawn from faucets by auto-pneumatic pumps at various working pressure by the expansion of compressed air from a 1,000-gallon air tank. To make this table of greater value an estimate of the amount of water used for various purposes on the farm is also given.

PUMPING CAPACITY OF AIR TANKS.

Working Pressure on Pump Gauge.	Total Pressure in Tank at Start.						
	40 lbs.	50 lbs.	60 lbs.	70 lbs.	80 lbs.	90 lbs.	100 lbs.
25 lbs....	375.	595.	833.	1075.	1310.	1548.	1786.
30 lbs....	221.	442.	663.	884.	1105.	1326.	1548.
35 lbs....	102.	306.	510.	714.	924.	1123.	1327.
40 lbs....	....	187.	374.	561.	748.	936.	1123.
45 lbs....	....	85.	255.	425.	596.	765.	936.
50 lbs....	....	....	153.	306.	460.	612.	765.
55 lbs....	....	....	68.	204.	330.	476.	612.
60 lbs....	....	....	....	119.	237.	375.	476.
65 lbs....	....	....	....	51.	153.	255.	357.

For air tanks of other than 1,000 gallons capacity, divide the above figures by 1,000 (move decimal point three places to the left) and multiply result by number of gallons the tank holds.

It takes .43 lbs. pressure per square inch for every foot that water is forced upward in a standpipe or elevated tank. For instance, if water is forced 20 ft. high, 20 × .43 = 8.6 lbs. pressure per square inch is secured; 40 ft. high gives 17.2 lbs. pressure; 60 ft. high, 25.8 lbs. pressure.

Reversing the foregoing proposition, every pound pressure per square inch in a service pipe elevates water 2.31 ft. high. If there are 15 lbs. pressure per square inch in the service pipe, the water will be elevated 2.31 × 15 = 34.6 ft. high; 25 lbs. pressure elevates water 57.7 ft. high; 35 lbs., 80.8 ft. high, etc.

Amount of Water Required for Stock and Other Purposes.—Horses drink 5 to 10 gallons per day. Cattle drink 7 to 12 gallons per day. Hogs drink 2 to 2½ gallons per day. Sheep drink 1 to 2 gallons per day. With 40 to 50 lbs. pressure per square inch, an ordinary ¾-in. garden hose nozzle requires about 6 gallons per minute, when throwing a solid stream, or about 4 gallons when spraying. It requires about 8 gallons to sprinkle 100 sq. ft. of lawn; 16 to 20 gallons will soak it thoroughly. It requires about 1½ gallons to fill an ordinary lavatory; 30 gallons to fill the average bath tub. It requires about 7 to 10 gallons to flush a closet. 300 gallons is a fair estimate of the amount of water required by the average sized family in 24 hours.

Only power driven outfits should be considered where any considerable amount of water is to be used. In this connection it may be stated that the amount of water

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FIGURE 1. Engine or Electric

ing, as inclement weather makes
ship. This is especially true dur-
of winter. With a water pres-
an easy matter to fit up a tank
animals are kept so that stock
exposure.
ater can be delivered under pres-
methods: First, the elevated tank;
tank; and third, the auto-pneumatic
ank system depends for its working
on a substructure high enough to
e to force water to the highest story

System.—A pneumatic tank system
pump, an air-tight steel tank, neces-
and valves, and power for operating
ystem may be a small one, operated by
or it may consist of a large pump ope-
ful engine, with two or more tanks of

ped into the bottom of the tank near one
e 2. To the bottom of the tank near the
nnected the discharge main from which
be extended to the kitchen, bathroom,

Is Required.—If water is pumped into the
pressure gauge registers 25 lbs., water can
0 ft. above the tank. If a faucet 20 ft. above
opened, water is discharged until the pres-
to 8.6 lbs., when it stops. The tank does not
ure enough to deliver the remaining water 20
It is also found that when air is compressed
e tank with water, the water gradually absorbs

heating, or at least so arranged that these may easily be put in place. Heating from the range is in a measure

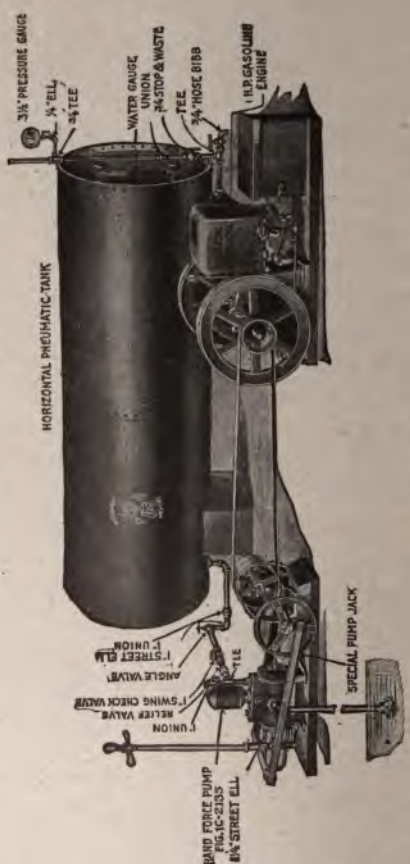

FIGURE 2.
Pneumatic Water System, Combined Hand and Power.

more satisfactory than from a furnace, as the range is more likely to be used the year round. Plans for the barn should also be made with a view to having water

brought into the building, as inclement weather makes caring for stock a hardship. This is especially true during the severe weather of winter. With a water pressure system it becomes an easy matter to fit up a tank in all buildings where animals are kept so that stock can be watered without exposure.

For farm homes, water can be delivered under pressure by three different methods: First, the elevated tank; second, the pneumatic tank; and third, the auto-pneumatic pump. The elevated tank system depends for its working upon a tank placed on a substructure high enough to give sufficient pressure to force water to the highest story of the building.

Pneumatic Tank System.—A pneumatic tank system consists of a force pump, an air-tight steel tank, necessary pipe, fittings and valves, and power for operating the pump. The system may be a small one, operated by hand or windmill, or it may consist of a large pump operated by a powerful engine, with two or more tanks of large capacity.

Water is pumped into the bottom of the tank near one end. See Figure 2. To the bottom of the tank near the other end is connected the discharge main from which branches may be extended to the kitchen, bathroom, laundry, etc.

Why Air Is Required.—If water is pumped into the tank until a pressure gauge registers 25 lbs., water can be forced 60 ft. above the tank. If a faucet 20 ft. above the tank is opened, water is discharged until the pressure falls to 8.6 lbs., when it stops. The tank does not have pressure enough to deliver the remaining water 20 ft. high. It is also found that when air is compressed in the same tank with water, the water gradually absorbs

the air, and the air requires constant renewal. Both troubles are overcome by compressing excess air in with the water until the pressure gauge registers 25 lbs., when the tank is half full of water. This excess air pressure is secured in a number of ways: (1) An air intake valve may be placed in the suction pipe, and controlled by hand; (2) a combined air and water pump may be used; (3) when power is available, use an air compressor, which may be operated whenever air is required. The "working capacity" of a tank is about two-thirds its total capacity.

FIGURE 3.
Bathroom.

The tank usually used has a capacity of 420 gallons, which, allowing one-third for air space, will deliver about 280 gallons of water at one pumping. Other sizes of tanks can be used.

For operating the pump by power, a small gasoline engine may be placed as shown in Figure 2. the po

being transmitted from engine to pump by means of a belt. Fairbanks-Morse Co. supply an engine of this type which they designate as "Jack Junior," 1 h.p. The pump should be set within 18 or 20 ft. of low water level. The steel tank for a pneumatic tank system should be made of boiler steel, riveted same as a steam boiler, and tested before shipment to a pressure of 125 lbs. per square inch. They are furnished with one head dished outwards and the other head dished inwards. A manhole for cleaning purposes should be fitted in one end. Figure 2 shows the tank in a horizontal position. It may be placed in a vertical position if more convenient. In the vertical tank the inlet pipe is connected to one side of the tank near the bottom end, while the discharge main connects to the opposite side near bottom end.

Auto-Pneumatic Pump.—The auto-pneumatic pump can be used in wells, springs or lakes, where the water is free from sand and mud, and where the water does not have to be lifted more than 100 ft., measured from the base of the pump to the highest point of delivery, or where the working pressure does not exceed 65 lbs.

This method makes it possible to deliver water under pressure without water storage, thus rendering it possible to have a constant supply of fresh water direct from the source of supply.

The system consists of one or more auto-pneumatic pumps, air-tight steel tank, and air compressor, and an engine or electric motor for driving the compressor. No water tank is required, for nothing is stored but compressed air. Compressed air is piped down to the auto-pneumatic pump in the well, and the water is discharged through pipe from the pump to the faucets, cool and fresh.

An automatic device makes the compressed air force the water out of two pump cylinders alternately, with a steady, continuous flow. The pump operates only while water is drawn at the faucets. It starts automatically

FIGURE 4.
Kitchen.

when the faucet is opened and stops when it is closed.

Two or more auto-pneumatic pumps may be installed in different wells or cisterns and connected to the same air tank.

An intake well is built near the bank of a lake and an intake pipe, protected by a strainer, connects it with the lake. At slight cost a filtering box of fine gravel and charcoal may be constructed in the lake to protect the strainer. In this way the water is purified for drinking purposes. The intake well forms a protection for the pump, and permits the system to be used throughout the winter.

For air tanks of other than 1,000 gallons capacity, divide the above figures by 1,000 (move decimal point three places to the left) and multiply result by number of gallons the tank holds.

The size of pipe is designated by the inside diameter. The size of valves and fittings is designated by the size of pipe for which they are threaded.

A gallon of water weighs 8⅓ lbs. and contains 231 cu-in. A cubic foot of water weighs 62½ lbs. and contains 1,728 cu. in., or 7½ gallons; 31½ gallons of water constitute a barrel.

TABLE FOR CONVERTING FEET HEAD OF WATER INTO PRESSURE PER SQUARE INCH.

Feet Head	Pounds per Square Inch	Feet Head	Pounds per Square Inch	Feet Head	Pounds per Square Inch
1	.43	25	10.83	85	36.81
2	.87	30	12.99	90	38.98
3	1.30	35	15.16	95	41.14
4	1.73	40	17.32	100	43.31
5	2.17	45	19.49	110	47.64
6	2.60	50	21.65	120	51.97
7	3.03	55	23.82	130	56.30
8	3.40	60	25.99	140	60.63
9	3.90	65	28.15	150	64.96
10	4.33	70	30.32	160	69.29
15	6.50	75	32.48	170	73.63
20	8.66	80	34.65	180	77.96

TABLE FOR CONVERTING PRESSURE PER SQUARE INCH INTO FEET HEAD OF WATER.

Pounds per Square Inch	Feet Head	Pounds per Square Inch	Feet Head	Pounds per Square Inch	Feet Head
1	2.31	25	57.72	85	196.26
2	4.62	30	69.27	90	207.81
3	6.93	35	80.81	95	219.35
4	9.24	40	92.36	100	230.90
5	11.54	45	103.90	110	253.98
6	13.85	50	115.45	120	277.07
7	16.16	55	126.99	125	288.62
8	18.47	60	138.54	130	300.16
9	20.78	65	150.08	140	323.25
10	23.09	70	161.63	150	346.34
15	34.63	75	173.17	160	369.43
20	46.18	80	184.72	170	392.52

TIME REQUIRED TO CHARGE AIR TANK.

To estimate the time in minutes to charge air tank from zero to a maximum pressure, divide the total number of gallons in tank by 7½, multiply result by maximum pressure in pounds per square inch, and divide by 15 (one atmosphere), and multiply by displacement of compressor in cubic feet per minute. Add 20 per cent to 25 per cent for loss due to friction, slippage, etc.

TABLE SHOWING NUMBER OF GALLONS OF WATER DELIVERED AT DIFFERENT PRESSURES WHICH IT WILL BE PROJECTED THROUGH NOZZLES.

Pounds Pressure at Nozzle	Diameter of Nozzles ¾-Inch Height Jet, Feet	¾-Inch Gallons Per Min.	1-Inch Height Jet, Feet	1-Inch Gallons Per Min.
4.3	9.7	22.7	9.7	45.4
8.6	19.0	32.2	19.0	64.4
13.0	27.7	39.4	27.7	78.8
17.3	36.0	45.5	36.0	90.9
21.6	44.0	50.9	44.0	101.8
26.0	51.0	55.7	51.0	111.4
30.3	58.0	60.1	58.0	120.2
34.6	64.0	64.3	64.0	128.6
39.0	70.0	68.3	70.0	136.6
43.3	75.0	72.0	75.0	144.0
52.0	84.0	78.8	84.0	157.6
60.6	91.0	85.2	91.0	170.4
69.3	96.0	90.8	96.0	181.6

Pounds Pressure at Nozzle	Diameter of Nozzles ¾-Inch Height Jet, Feet	¾-Inch Gallons Per Min.
4.3	9.7	22.7
8.6	19.0	32.2
13.0	27.7	39.4
17.3	36.0	45.5
21.6	44.0	50.9
26.0	51.0	55.7
30.3	58.0	60.1
34.6	64.0	64.3
39.0	70.0	68.3
43.3	75.0	72.0
52.0	84.0	78.8
60.6	91.0	85.2
69.3	96.0	90.8

General Information.—A cubic foot per second equals 450 gallons per minute. An acre-foot is 325,829 gallons. The term "miner's inch" of water is more or less indefinite, but is approximately equal to a flow of 11¼ gallons per minute. This varies in different states from about 9 to 13 gallons per minute.

Diameter multiplied by 3.1416 equals circumference. Circumference multiplied by .3183 equals diameter. The square of the diameter multiplied bv .7854 equals area.

To find the diameter of a pump cylinder required to move a given quantity of water per minute, the piston travel being 100 ft. per minute, divide the number of gallons by four, then extract the square root, and the result will be the diameter in inches.

To find the area of required pipe, the volume of water being known, multiply the number of cubic feet of water by 144 and divide the product by the velocity in feet per minute. This gives the area of pipe, from which it is easy to determine the diameter.

To find the velocity in feet per minute necessary to discharge a given volume of water in a given time, multiply the number of cubic feet of water by 144 and divide the product by the area of the pipe in inches.

In figuring the actual horse power required to operate a pump, the "friction head" should be added to the "actual head," or elevation. This is given in the table on the preceding page.

Using the above formulae and including the "friction head," will give the theoretical horse power. To figure the actual horse power required it is necessary to know the efficiency of the pump. To illustrate:

If the efficiency of a small pump is 33 1-3 per cent, the actual horse power required is three times the theoreti

If the efficiency is 50 per cent, the actual horse power is double the theoretical.

If the efficiency is 66 2-3 per cent, the actual horse power is 1½ times the theoretical, etc.

ACRES IRRIGATED BY VARYING QUANTITIES OF WATER.

Making due allowance for evaporation, it requires 28,320 gallons of water to irrigate one acre one inch deep.

The following table taken from government tests shows the number of acres irrigated in 1, 10 and 24 hours, pumping various quantities, and irrigating various depths, local conditions, of course, vary and this table has been compiled from a comparison of various sections.

Gallons Pumped per Min.	Acres Irrigated in 1 Hour					
	1 In. Deep	2 In. Deep	3 In. Deep	4 In. Deep	5 In. Deep	6 In. Deep
600	1.3	.6	.4	.3	.2	.2
824	1.8	.9	.6	.4	.3	.3
944	2.1	1.0	.7	.5	.4	.3
988	2.2	1.1	.7	.5	.4	.3
1000	2.2	1.1	.7	.5	.4	.3
1200	2.6	1.3	.9	.6	.5	.4
1500	3.3	1.6	1.1	.8	.6	.5
2000	4.4	2.2	1.4	1.1	.9	.7

Gallons Pumped per Min.	Acres Irrigated in 10 Hours					
	1 In. Deep	2 In. Deep	3 In. Deep	4 In. Deep	5 In. Deep	6 In. Deep
600	13.2	6.6	4.4	3.3	2.6	2.2
824	18.2	9.1	6.0	4.5	3.6	3.0
944	20.8	10.4	6.9	5.2	4.1	3.4
988	21.8	10.9	7.2	5.4	4.3	3.6
1000	22.1	11.0	7.3	5.5	4.4	3.7
1200	26.5	13.2	8.8	6.6	5.3	4.4
1500	33.1	16.5	11.0	8.2	6.6	5.5
2000	44.2	22.1	14.7	11.0	8.8	7.3

Gallons Pumped per Min.	Acres Irrigated in 24 Hours					
	1 In. Deep	2 In. Deep	3 In. Deep	4 In. Deep	5 In. Deep	6 In. Deep
600	31.8	15.9	10.6	7.9	6.3	5.3
824	43.7	21.8	14.5	10.9	8.7	7.3
944	50.0	25.0	16.7	12 5	10.0	8.3
988	52.4	26.2	17.4	13.1	10.4	8.7
1000	53.0	26.5	17.6	13.2	10.6	8.8
1200	63.6	31.8	21.2	15.9	12.7	10.6
1500	79.5	39.7	26.5	19.9	15.9	13.2
2000	106.0	53.0	35.3	26.5	21.2	17.6

It requires from 10 ins. to 20 ins. of water per acre to produce a crop by irrigation, the average being 16 ins. The actual amount required depends upon the crop and the season.

CHAPTER II.

ELECTRIC LIGHT FOR FARM HOMES

The gasoline engine makes it possible for the farmer to have his house and adjacent outbuildings equipped with electric light at a moderate expense. The safety and cleanliness of electric light as compared with kerosene lamps, gas, or in fact any other method of lighting, is beyond all question. Especially does this apply in the case of the barn, the dairy and other necessary outbuildings, where, instead of having to use matches for lighting the gas jet or lamp, which at the best supply but a dim light covering a limited area, an abundance of clear white light is instantly available by the turning of a switch.

In the house, in addition to the inestimable advantage of having the best of light in the evening, electric fans may be installed, which will furnish cooling breezes in the summer, while electric flat irons, electrically operated sewing machines, vacuum cleaners, and even small cooking devices, will greatly lessen household work.

Gas or oil engines for operating electric lighting systems require to be specially constructed in order to secure close speed regulation, which is a paramount requirement in this particular service.

They should be equipped with a throttling governor instead of the ordinary hit-and-miss type, and the flywheels should be extra heavy in order to insure a smooth-running engine. The engine can be belted to the

dynamo, or if desired, a direct-connected outfit may be obtained in which the dynamo is connected direct to the engine shaft.

A speed regulation within 2 per cent should be obtained when running under a constant load. This insures a good steady light.

Figure 6 shows a combined electric light and pumping plant, which can be utilized for either purpose.

FIGURE 6.
Combined Fresh Water and Electric Light System.

Figure 7 shows an outfit designed exclusively for electric lighting. It is called a low voltage, residence lighting outfit. This plant consists of a 50-light dynamo, a 2 h.p. gasoline or kerosene engine, an endless belt for running the dynamo, a switchboard, a storage battery and 50 lights with fixtures and shades, wired and ready for hanging.

The dynamo is a 25-ampere, 32-volt, multi-polar compound wound machine. It is automatic in operation and

maintains a constant voltage, whether one lamp, or all are in use, and thus generates just sufficient current to supply the demand. It is self-oiling, requires little attention, and the low voltage at which it operates is practically harmless.

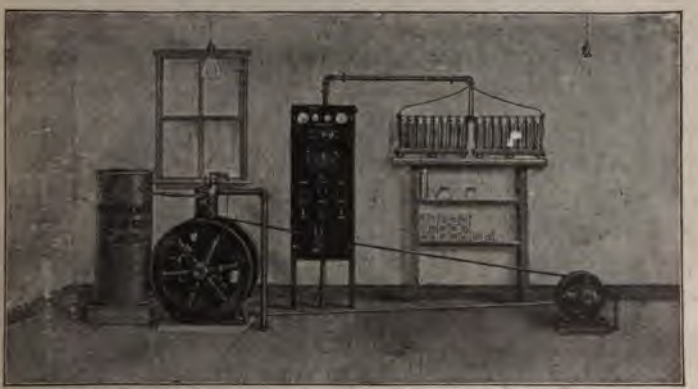

FIGURE 7.

Gasoline Engine. Switchboard. Storage Battery. Dynamo.

Figure 8 is an enlarged view of the switchboard, showing the various necessary devices accompanying it. By closing the main switch, current is sent through the lamp circuit, and closing the two battery switches charges the storage battery; while by pulling these two switches and the dynamo or main switch open, the lamps will receive current from the storage battery. The lamps to be used with this lighting outfit consume 15 watts each and give 12 candle power, their average life being 1,000 hrs. each when operated at their normal voltage.

The storage battery furnished with this outfit is intended as an auxiliary to furnish lights when it is not con-

venient to run the engine. When fully charged it will run eighteen lights for 2¾ hrs., thirteen lights for 4¾ hrs., or nine lights for 7½ hrs. For ordinary occasions it will

FIGURE 8.

be found large enough to run the lights of a small residence one or two evenings without running the engine, but this is not so efficient as running lights direct from the dynamo.

The normal rating of the battery is the number of lamps that it will run for 7½ hrs., and it will run a smaller number for a longer time; for example, one-half as many for 15 hrs., or one-fourth as many for 30 hrs.; and when completely discharged it takes about 10 hrs. to completely

recharge it. Batteries should be selected that have ample capacity for the work contemplated, in order that it may not be necessary to run the engine at inconvenient times to carry the desired number of lights or to recharge the battery.

If it is desired, stronger lights than 12 candle power can be used, but care should be taken not to overload the standard 50-light dynamo. For every three 16 candle power Mazda lamps that are put on the circuit, take off four of the 12 candle power Mazda lamps; for every three 20 candle power Mazda lamps that are put on the circuit, take off five of the 12 candle power Mazda lamps.

The electrical unit of work is a watt. A kilowatt (k.w.) is 1,000 watts.

The watt rating of a machine is the product of the volts multiplied by the amperes.

While the engine will deliver more than 2 h.p., nevertheless the electrical capacity of the plant is limited to the capacity of the dynamo.

The plant will run as many lights, motors or other electrical devices, as desired, provided they are all made for 30 volts, and the total watt rating of all of them that are in circuit at any one time does not exceed 750 watts.

The 12 candle power Mazda lamps each take 15 watts; 50 of them, therefore, require 750 watts, which is practically the capacity of the outfit.

The 16 candle power Mazda lamps each take 20 watts, and the 20 candle power, 25 watts.

Electric motors, flat irons, curling irons, toasters, fans, etc., are all rated in watts and can be obtained for 30 volts, so it is easy to figure out just how many different devices, and what sizes may be operated simultaneously by the current supplied from a 50-light dynamo. For

instance, if it is desired to run an electric motor that requires 380 to 400 watts, then while it is running there would be only about 350 to 370 watts available for lights or other work.

General Information About Electric Lighting and Power Plants.—Electric power is measured in kilowatts, usually abbreviated k.w.; 746 watts equal one horse power and 1,000 watts equal one kilowatt, which is, therefore, equal to 1 1-3 h.p.

Dynamos are rated in kilowatts—a 1 k.w. dynamo will give out electric power equal to 1 1-3 h.p., but it will take a little more than 1 1-3 h.p. to drive it because there are slight losses due to friction in the bearings and heating of the wires.

Dynamos cannot be rated in lamps, for the reason that lamps take different amounts of electricity according to their candle power and the material of which they are made, and because there are losses in the wire between the dynamo and the lamps which use up a part of the dynamo's output and which vary with the size and length of the wire.

The ordinary 16 candle power, carbon filament lamp takes 50 watts—some take more than this and some less, according to their efficiency. Monarch Mazda lamps are made in various sizes; 15-watt lamps (low voltage only) give 12 candle power, 25-watt lamps give 20 candle power, 40-watt lamps give 32 candle power, and 60-watt lamps give 50 candle power.

Voltage is the pressure at which the electric current is generated and transmitted. Small residence plants are operated at 30 volts—large lighting plants are usually operated at 110 to 220 volts.

Small dynamos are usually belt driven, but may be

direct connected to the engine. Large dynamos are often direct connected because floor space is saved and the use of a belt avoided, but this system is more costly than belt driving and its chief advantage lies in the economy of space.

A steady, uniform speed of the dynamo is necessary for electric lighting, otherwise the lights will flicker. Hence, a close regulating high grade engine is necessary.

PART III

PART III.

CHAPTER I.

THE SCIENCE OF THRESHING

Cylinder.—The usual form of construction of a threshing cylinder consists of parallel bars secured to the heads or spokes by means of bands shrunk around them, the cylinder teeth being inserted through the bars and secured by nuts on the inside. There are usually 12 or 20 bars (see Figures 1 and 2), the object being to increase the weight of the cylinder by using more and heavier bars, to insure a more uniform and steady motion.

The cylinder should be kept thoroughly in balance. When the cylinder is out of balance the fact is easily detected by the jarring or short vibrations in its vicinity. This may be noted by placing a hand on the framework near the cylinder boxes. The side on which this is most plainly felt indicates the end of the cylinder at fault.

If permitted to run so, it will have a tendency to cause the cylinder boxes to heat and wear out much more rapidly, and also has a tendency to flatten the cylinder shaft on the side that receives the wearing strain. A smoothly running cylinder requires much less power to drive it; as whatever force it takes to cause the vibration

is so much power lost, besides interfering with the working and lasting qualities of the machine. Excessive vibration has a tendency to loosen the framework of the entire machine.

A cylinder may be put in balance by removing it and

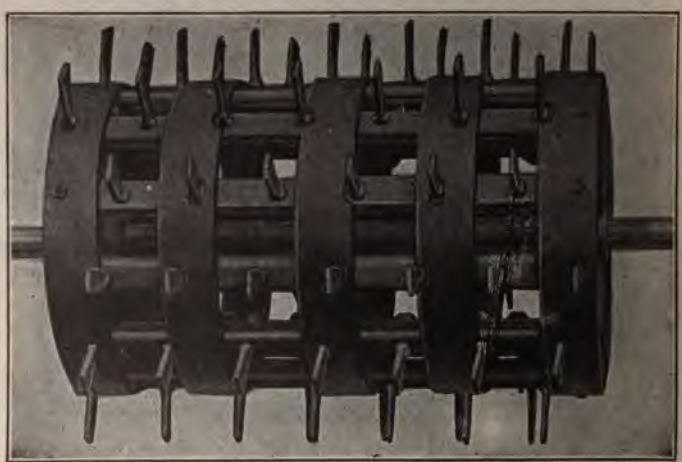

FIGURE 1.
Showing a 12-Bar Cylinder.

placing it on two straight edges set up edgewise to receive the journals of the cylinder shaft. The squares or straight edges should first be trued up with a spirit level, and may be held in position on edge by driving spikes on either side. The cylinder will adjust itself by turning on the straight edges, the heavier side going down. Wedges, or pieces of iron of sufficient weight, should be driven in between the band and head on the light or upper side of the

cylinder to cause it to balance or remain without turning in any position in which it may be placed.

If cylinders are properly balanced when they come from the shop this method will usually put them in good working order. However, a cylinder may indicate to be in

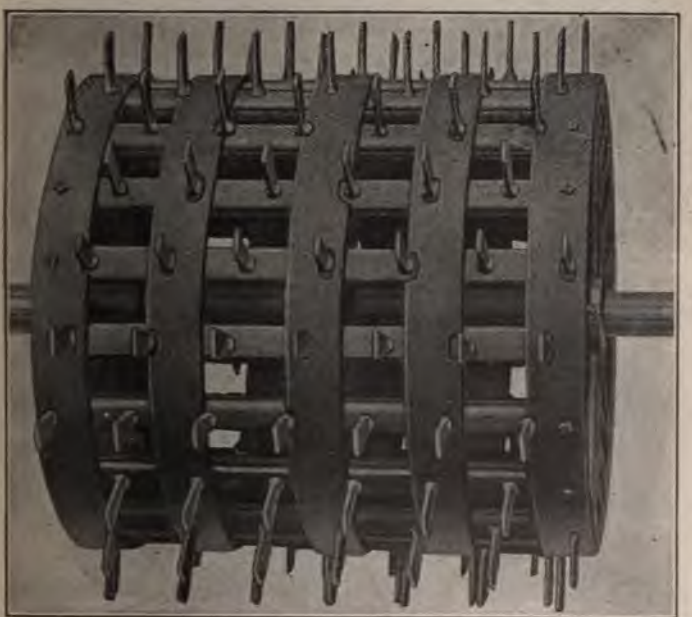

FIGURE 2.
Showing a 20-Bar Cylinder.

perfect balance on the straight edges but in motion in the machine not so, the cause being that one end is heavier on one side while the other end of the cylinder is correspondingly heavy on the opposite side, thus preventing

the straight edges from indicating which is the heavier side. In such case the cylinder should be revolved at a rapid speed in loose boxes, and while in motion a piece of chalk held stationary near enough to the shaft at the journal to slightly mark it. This will indicate the light side, and a balancing piece should be inserted as before. Both ends should be trued in the same manner.

A cylinder is sometimes thrown out of balance by putting in part new teeth, leaving a part of the worn ones in, and not having them evenly distributed around the cylinder. In this case the remedy is to put in all new teeth where they are much worn.

The function of the cylinder is to loosen the kernels from the straw. This is accomplished by the cylinder tooth striking the unthreshed head with sufficient force to jar the kernels loose from the chaff. The cylinder should be run with sufficient speed to entirely free all the kernels, and not leave any in the straw. If for any reason the cylinder does not do its work thoroughly, the result is the wasting of grain. In some instances some of the kernels will be partially loosened, but adhere to the head until nearly through the machine, when they will fall out and be carried along with the straw to the straw stack, thus making it appear that the fault is in the separating apparatus, when it is really in the cylinder.

The ordinary speed of a cylinder is from 750 to 1,075 r.p.m., giving a speed of about 6,000 ft. per minute to the teeth.

The cylinder boxes, or journal bearings, should be adjusted endwise so as to bring the cylinder teeth midway between the concave teeth.

End play of the cylinder journals should be avoided as much as possible. The separator should stand stif

on its trucks while in operation, as its vibration consumes power.

Concaves (Figure 3) should be sufficiently strong to stand the enormous strain they are subjected to in "slugging" or threshing damp grain. Care should be used to

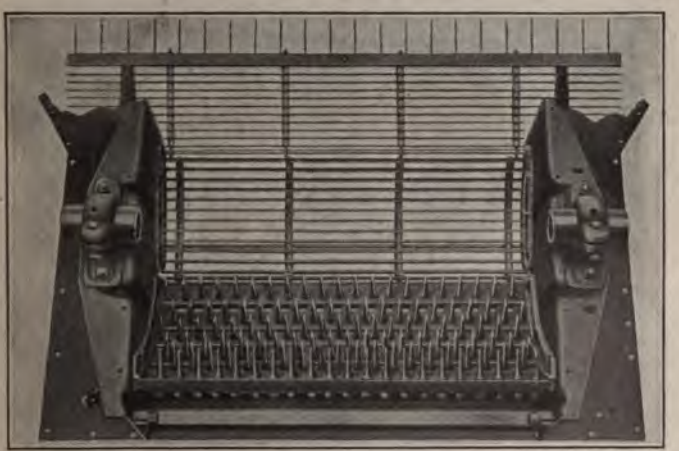

FIGURE 3.

View, Looking Down on the Concaves and Grates in a Case 20-Bar Cylinder Machine. Pressed Boiler-Steel Sides.

see that none of the teeth are too long or permit the concave being raised to its full height without striking. There should be stops provided to keep the concave from raising too high at either end. These should be adjusted to allow it to be raised as high as possible without striking the teeth. It is good practice to use the concave set clear up, and use less rows of teeth, rather than to use more teeth and lower the concave. In the latter case it leaves a

space below the points of cylinder teeth to permit whole heads to pass without being acted upon sufficiently to shell the kernels out. When the work will permit, remove one or more of the concaves and insert blanks without teeth. However, in some cases where the straw is very dry and brittle and inclined to break up badly, the concave may be lowered a little to advantage. Some are constructed to adjust both rear and front. It is contended by some that a cylinder is less liable to "slug" when the concave is lowered in the rear and raised in front, than when up in the rear and down in front, on account of the wedge shaped angle presented for the straw to enter.

Feed Board.—In hand feeding the tables and feed board should be kept smooth and free from nails to facilitate the moving of the straw. If the cylinder does not have draft enough, or take the straw free enough, it may be helped by rounding or curving the lower edge of the feed board that comes in contact with the concave. The straw will pass over this rounded portion more freely than it would pass the sharp angle, and be broken, or cut up less, a desirable point to be gained.

It is good practice to keep the lower edge of the feed board on top of the concave, close to the cylinder teeth even when the concave is lowered somewhat. Then every head will be acted upon by the cylinder teeth as it enters, otherwise it might pass along close to the bottom of the concave unthreshed.

Grates.—The grates (Figure 3) back of the concave are very essential to assist in separation, if the spaces between the grates are of sufficient width to freely permit flying kernels to fall through. The adjustment should be such that the straw passing from the concave will strike

the surface of the grate at a slight angle. This will assist in the separation by directing the kernels through it. The action of the passing straw will also tend to keep the grate clean, and prevent it from loading up with chaff and sticks.

Teeth.—The cylinder teeth should pass midway between the concave teeth. Any bent ones may be straightened with a heavy hammer, and the cylinder boxes adjusted edgewise to make all the teeth run squarely in the center. If permitted to have too much end play or run too close together it will cause cracking of the grain and chop the straw up too much; besides it may leave a correspondingly large opening at one side of the tooth that will permit heads of grain to pass unthreshed.

The teeth shell the kernels from the head by striking them with such force as to jar them loose. The concave teeth are for the purpose of retarding the speed of the straw while receiving the action of the cylinder teeth. Only enough concave teeth should be used to hold the straw until threshed clean, as more would have a tendency to chop up the straw and consume unnecessary power. It also makes separation more difficult to have the straw cut up, as it packs together more than if the stalks are left comparatively whole.

The teeth sometimes become loose and cause delay. This is more true of new teeth when being first used. This is on account of their not fitting perfectly, and the terrible strain they are subjected to when the straw is compressed in passing through, causes them to move in the bar slightly and each time they move the nut loosens a little and they are soon loose enough to strike and rattle. When new teeth are put in they should be watched carefully and tightened up occasionally until well seated,

when they will stay without further attention. But the practice of some threshers is to give the teeth no attention until they begin to rattle and make a noise. Much time will be saved by going over the entire cylinder, having new teeth, with the wrench once or twice a day and see that every nut is set up tight. Many devices have been tried to keep the nuts from working loose, some of which

FIGURE 4.

Interchangeable, Annealed and Tempered Cylinder and Concave Tooth, Nut and Spring Washer.

have points of merit. Some use wooden bars inside of the cylinder bars; the spring or natural tension of the wood serving to permit the tooth to spring a little and still remain tight. A twisted or spiral steel bar on the inside has been used to take up the wear. Teeth do not seem to loosen as badly in double bar as in single bar cylinders on account of the extra length of the shank to hold them from side movement of the tooth when the straw passes in in excessive quantities. Figure 4 illustrates one method, which is in use, by which to hold the nuts from turning by using a spring steel washer under the nut. Both square and round shanks are in use. Teeth should be made of steel, sufficiently hard to prevent too rapid wear.

Worn cylinder teeth prevent the straw from entering the cylinder freely. They should be replaced by new ones as soon as they become very much worn.

Beater.—The function of the beater is to take the straw from the cylinder as fast as it is threshed and pass it back to the separating device. The usual form of this device is a fan-like drum set in such a position that the straw and grain as it comes from the cylinder will pass either under or over it.

It also serves as a check to the flying kernels from the cylinder which would otherwise be thrown back into the straw and thus retard separation. Another device used for this purpose is attached to some machines. It consists of a set of forks placed to work over a slatted rack located back of the cylinder. Other forms of beaters are used, while some machines work very well without a beater, letting the cylinder deliver direct to the separating device.

The Check Board is a sheet iron apron hung just back of the beater. Its function is to arrest flying kernels. It should be sufficiently long and adjusted to come down low enough to arrest all flying kernels that come from the beater and cylinder, otherwise they would be thrown back on top of the straw so far towards the rear of the machine as to be lost with the straw.

Separating Devices.—One of the most important features of a thresher is the separating device, the function of which is to receive the straw and grain as it comes from the cylinder, and pass the straw to the stack, and direct the grain to the shoe or fanning mill to be cleaned. While there are many different types of separators in use, they may be divided into two or three general classes. First, there is the vibrating or oscillating rack or table,

see Figure 5, and second, the traveling saddle or straw rack. Third, there may be a combination of these two. There are also accessories used in connection with these, such as revolving pickers or rakes, beaters, and fingers. The [illegible] of separating racks or tables are usually

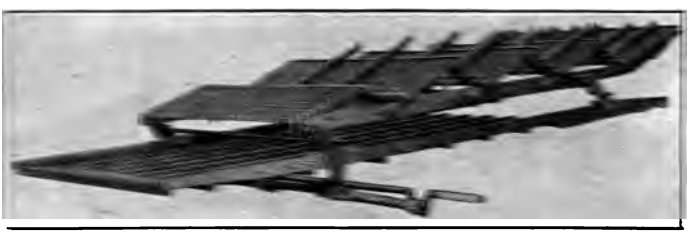

FIGURE 5.

Straw Rack and Grain Pan.

[illegible] spaces through which the [illegible] straw is being carried along on [illegible] the moving rack. In some types this [illegible] means of a crank, is [illegible] while in others the rack [illegible] revolution, the object of the [illegible] straw in such a manner as to [illegible] and at the same time keep the straw [illegible] the rear of the machine. The [illegible] on the under side of a [illegible] compress it at each [illegible] The straw of its own elasticity [illegible] while up in the air [illegible] rack.

The straw [illegible] a succession of jars or shocks [illegible] more effective when the straw [illegible] with the rack on its

rising motion at one-half its stroke, because the rack travels at its highest speed at this point of its stroke. As the rack continues its upward stroke its speed gradually decreases until the top end of the stroke is reached. The same may be said of the down stroke. This is due to the peculiarities of the crank motion by which it is operated.

The motion of the rack should be such that its upward stroke will cause the straw to continue its course slightly and permit the rack to descend from beneath it. Gravity then will begin to act upon the straw and cause it to start on its downward motion; the straw at first moves very slow but increases its speed as it descends toward the rack, and the momentum thus attained will cause it to strike the ascending rack with a sharp and jarring motion at the midway point before mentioned, if it has been properly timed. The weight of the straw will cause it to be pressed against the rack with force, while the stiffness of each straw that comes in contact with the rack will have a tendency to move it as related to its neighbor, and as soon as released at the upward end of the stroke it will again expand to its normal condition.

This jarring, compressing and expanding movement accomplishes the desired result in a remarkably perfect manner, when the vibrating column of straw is not too thick and bulky. If the column of straw is so deep that the jarring motion of the rack is not felt through its entire column, the results are not as good. The upper part of the column of straw will float along without receiving the essential jarring motion of the rack on account of the springiness or elasticity of the intervening straws. While on the other hand if the rack is made to vibrate faster, and to throw the straw higher, the tendency is to also throw

see Figure 5, and second, the traveling raddle or straw rake. Third, there may be a combination of these two. There are also accessories used in connection with these, such as revolving pickers or rakes, beaters, and fingers. The various types of separating racks or tables are usually

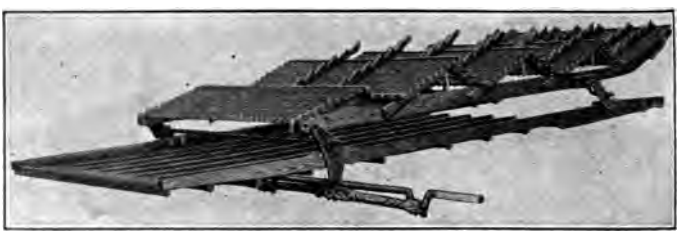

FIGURE 5.
Straw Rack and Grain Pan.

constructed of slats, leaving spaces through which the grain may fall while the straw is being carried along on the upper surface of the moving rack. In some types this motion, which is imparted by means of a crank, is concave, in others it is convex, while in others the rack is caused to make a complete revolution, the object of the motion being to agitate the straw in such a manner as to permit the kernels to fall, and at the same time keep the straw moving along toward the rear of the machine. The ordinary vibrating rack acting on the under side of a quantity of straw tends to jar and compress it at each upward stroke of the rack. The straw of its own elasticity expands to its normal condition while up in the air free from the rack.

The straw thus receives a succession of jars or shocks on its under side which will be more effective when the straw in falling comes in contact with the rack on its

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the grain; being of the greater specific gravity, it will continue its upward course in excess of the straw if the opportunity presents itself and thus retard separation.

The ordinary raddle is constructed of belting running over pulleys with laterally secured slats that will permit the grain to fall through and carry the straw along on their upper side. They seem to accomplish their work in a more perfect manner when their motion is quite rapid, as this keeps the sheet of traveling straw much thinner, thus giving the kernels a better opportunity to fall out. The raddle should be of sufficient length to give the kernels ample time to fall clear through the slats before reaching the end.

Some raddles are agitated while in motion by causing them to travel over an irregularly shaped pulley, which produces a rapid jarring motion, having a tendency to move the stalks of straw slightly among themselves. The point of contact where the straw falls on the raddle needs special attention. The straw at this point should be quite thin and loose. If in large or hard bunches, the tendency is to carry them along in one mass, not giving the kernels a chance to fall out. The separation will be more effective if the straw can fall a little distance so as to be traveling at right angles to the line of motion of the raddle when contact occurs. In the combination of the vibrating rack with the raddle, the straw usually passes over the rack first and then onto the raddle. At the point of delivery the action of the raddle pulls the straw apart and thins it, the tendency of the raddle being to take the straw much faster than the rack delivers it.

The Shoe, or cleaning mill, is an important part of the separator and upon it depends largely the good work

of the machine. In separating the grain from the straw there is a large amount of chaff and refuse delivered to the sieves with the grain. This is cleaned from the grain by passing it over a series of sieves through which a blast is being forced. A great deal depends on the perfect working of the shoe, its function being to thoroughly clean the grain without waste, and in quantities as fast as delivered to it.

There are three things to be considered in a shoe, and on the arrangement of these three depends its working, viz., the sieves, the blast and the motion. The sieves should be adapted to the kind of grain being threshed, and as few used as are necessary to do the work, as more retard the blast and catch straws and sticks. The blast should be sufficiently strong to insure its continued flow through the sieves, even when they are heavily loaded. The motion should be sufficiently strong to insure the chaff and kernels being moved on the surface of the sieve.

The Fans for producing the blast are usually constructed of a centrally revolving shaft with radiating arms, on which are secured fans to cause the air to rotate with it and produce the blast by admitting it at the ends, and forcing it out by centrifugal force at the periphery.

Some are revolved in one direction and some in the other. Those where the top of the fan travels toward the sieves are called overblast fans, and when constructed to revolve in the opposite direction, they are called underblast fans. Both styles are in common use and accomplish the work intended. There is a large variety of sieves made and used. Of late years the inclination seems to be favorable to the perforated metal and corru-

gated iron sieves, though wood and wire sieves are in use. The proper qualifications of a sieve are to permit the grain to fall through, pass the chaff and sticks over it, direct the proper amount of blast in the right direction and prevent the straws and sticks being retained in the meshes. The usual practice is to use a sieve adapted to each class of work, though there are some combinations that operate well on different kinds of grain. The usual plan is to have the upper sieve, called the chaffer, secured permanently, and of sufficiently large mesh to adapt it to the coarsest kinds of grain, while the lower ones are made interchangeable, to be varied according to the kind of work to be done. The openings in the sieve should be of sufficient size to permit the clean kernels to pass freely, and only enough of said openings to allow the proper volume of air blast to pass through. These openings should be of such a nature as to cause the air blast to flow in a perpendicular direction.

The Blast is an important feature of a well regulated shoe. It should be of sufficient volume to lift all light matter, and of sufficient pressure or force to cause a continuous and uniform flow through the meshes of the sieves.

This blast should be strongest directly in the openings or meshes of the sieve, while a short distance above the surface it should be mild or light. This condition is secured by making the blind portion of the sieve in proper proportion to the opening of the meshes, which is found in practice to be 5 to 7. That is, the solid, or blind, portion of the sieve should be 5-12 of the surface, while the openings in the meshes comprise 7-12. This rule applies particularly when the course of the blast is at right angles to the surface of the sieve.

st should be sufficiently strong to insure its

continual flow under all circumstances and conditions, but not of enough speed to blow any of the grain over with the chaff. There is a difference between a blast of strong pressure and a blast of fast speed. A blast of air may be traveling comparatively slow and still go with force and be difficult to stop, like that produced from a slow-moving air pump; or it may be moving quite rapidly, but with no particular force more than the inertia produced by its own weight, like the breeze of a summer day or the stroke of a lady's fan. The least obstruction would stop or turn such a blast. The kernels of grain will fall through a blast of any pressure or strength, but will not fall through a very fast-traveling blast.

The chaff is easily lifted on account of its light specific gravity. To do good work then, it requires a mild or slow blast delivered with strength or force. This blast should be spread under the entire surface of the sieve and be made to flow through every mesh. It should be the strongest and of greatest quantity at the front end of the sieve where it receives the grain and chaff, for it is here where the greatest work is to be done in lifting the sheet of chaff intermingled with grain, and decrease in quantity and pressure toward the rear end where less work is required. Then if a light kernel has been lifted with the chaff at the front end, it will give it a chance to fall before reaching the rear end of the sieve.

If the blast is made to pass through the chaff as soon as it enters the upper sieve, it will lift it and cause it to separate and expand, the lightest flying out first, giving the kernels a free opportunity to fall through the sieve much more quickly than if the blast were not

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strong enough to keep the meshes open and cleared of chaff. Besides, if the blast ceases to flow through any of the meshes, the fine dust and chaff will fall through and cause the second sieve to be overloaded, and thus the grain may retain a part of the chaff and dirt. The motion of the shoe should be sufficiently strong and rapid to move the grain and chaff on the surface of the sieves. Too strong a motion will interfere with the kernels in falling through the meshes properly and cause the grain to be carried over, either with the chaff or into the tailings spout. It is found in practice that the upper sieve or chaffer requires a longer and more positive stroke than the lower sieves. This is on account of the excessive quantities of chaff and cut up straw to be carried along. For this reason the upper sieve is usually placed in a different frame and given a longer stroke while those in the shoe receive a shorter and more rapid stroke.

The coarser and looser the material to be handled, the longer and more vigorous the motion should be. The straw rack loaded with loose fluffy straw requires quite a long stroke to be effective. The conveyor and chaffer sieves will use less, and the shoe sieves still less.

It will be seen, that if the straw rack had no more motion than the shoe it would scarcely move the straw at all. On the other hand, if the shoe had as much motion as the straw rack, it would throw the grain in such a fierce manner as to prevent much of it from passing through the sieve. This is on account of the difference in elasticity, or springiness of the materials to be moved. It is then quite essential that the motion should be adapted to the class of work to be done. In end shake sieves, i.e., the stroke being endwise of the

machine, this motion should be upwards and backwards with more of an uplift, and should be only sufficiently strong or rapid enough to cause the grain to be carried along in as quiet a manner as possible.

The sieves should be stiff and rigid enough to prevent their springing much in the center, for if they do it will make the motion too strong there, causing the grain in the center of the sieves to be thrown too high, preventing it from properly falling through the meshes. This will be apparent when we consider the frame of the sieve traveling 2 ins. at each stroke, and making 250 strokes per minute, the sieve then will travel 500 ins. per minute. Now, if the sieve springs 1 in. each stroke, the center of the sieve has traveled 3 ins. each stroke, or 750 ins. each minute, which may be a motion entirely too strong, and it will be seen that the center of the sieve receiving the stronger motion will act upon the grain in a more vigorous manner than the portion of it which has less motion.

It is also necessary for a shoe having a weak blast to have a stronger motion to assist in carrying off the refuse and chaff at times when the blast is overtaxed, such as in wet or damp threshing or when an undue amount of chaff and cut straw loaded with dust is delivered to it.

In side shake shoes, i.e., when the motion is sideways to the machine, the motion should be sufficiently strong and long to cause the sieve to move under the grain and chaff, and keep it in motion to aid the blast in carrying it along toward the rear end.

The blast may be at a greater angle from the perpendicular inside shake shoes, as it is the only means of carrying the chaff and refuse along to the rear. In

der continuously, will not slug it. To do this it is necessary that the bundles be drawn out or divided in some way that the cylinder may not receive the whole bundle at one time. One method of accomplishing this is to pass the lower portion of the bundle toward the cylinder slowly while the top portion has its speed increased by some faster traveling mechanism above it. This forces the top straws ahead, while the lower ones are being retarded, and must be accomplished before the bundle reaches the cylinder. The more completely this is done, the better the feeder and the better the machine will work. Some self-feeders are equipped with governors which regulate the amount being fed to the machine by disengaging a mechanism whereby the feeder is thrown out of gear when the speed of the cylinder is reduced below a predetermined number of revolutions per minute. This type is termed the speed governor. Another type is the straw governor, which regulates by the amount or bulk of the traveling column of straw.

The Straw Governor is an important improvement. It performs entirely different functions from the speed governor. The speed governor stops the entire feeder when the speed drops below a certain point. The straw governor does not depend on the speed for its action, but upon the volume of straw passing into the feeder. The "straw shoes," which are of channel-shaped steel, attached to a square shaft pivoted in front of the crankshaft, ride upon the stream of straw passing into the feeder. When this stream of straw is deeper than the straw governor is set for, it will cause the shoes to rise and disengage a clutch on the sprocket wheel driving the carrier.

The carrier is the only part of the feeder stopped by

the straw governor, and since the knife arms are between the straw shoes and do not stop, they quickly reduce the amount of grain under the straw shoes, allowing them to drop and start the carrier rake.

The length of the connection between the crank on the square shaft and the clutch arm is easily adjusted by means of a wing nut. This adjustment gives the operator complete control of the amount of grain going to the cylinder, and, if necessary, he can set the straw governor so that the feeder will feed but half a bundle at a time. The knife arms travel very rapidly, quickly reducing the amount of grain under the straw shoes, so that the carrier is stopped only a short time. In fact, the length of time it is stopped is often almost imperceptible, but prevents slugging of the cylinder.

Figure 6 shows a sectional view of the J. I. Case & Co. self-feeder equipped with the straw governor. The bundles in most feeders are first deposited on the carrier, which moves them along to the band-cutting device by means of a raddle constructed of belting with laterally secured slats, or canvas covered table. As the bundles move toward the cylinder, they are acted upon by the band cutters, which should be sufficiently near together and travel close enough to the table to insure all the bands being cut. The bundles should at the same time be thoroughly picked apart, and this function in most of the feeders is performed by the band-cutters in such a manner as to throw the top straws ahead toward the cylinder.

A properly constructed self-feeder requires but very little more power to thresh the same quantity of grain in the same time, as it divides up the bundles, and feeds clear across the cylinder much better than is done by ha-

PICTURE 6.

Self Feeder with Straw Governor Attached.

Also with the use of self-feeders the pitchers usually pass the bundles along a little faster because they do not have to use the same caution about placing them on the table as they do in hand-feeding, only observing the amount being handled.

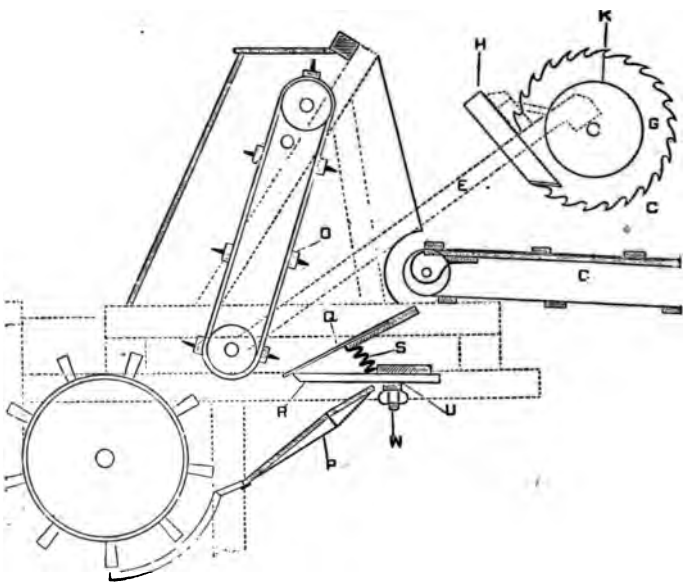


FIGURE 7.

Figure 7 represents another plan of self-feeder and band-cutter, and shows the arrangement of the different parts from which its working may be easily understood.

The bundles are placed on the carrier C; as they pass under the disc G the bands are caught up by the notched teeth and forced against the lower end of the cutting knives H. The frame E is hinged so the disc head may

adjust itself to the thickness of the traveling sheaves as they pass under it. The bundle carrier delivers the grain on to the retaining board Q, which is supported by the coil spring S.

The lower portion of the retaining board is slotted to permit the fingers R to project through, when the board is depressed by the grain being pressed against it by the traveling rake O, which takes the straw from the board Q and delivers it on to the feed board P, where it passes into the cylinder.

Instead of the discs G cutting the bands they serve only as pickers to pick up the bands and press them against the stationary knives H. There are enough discs and knives arranged across the carrier to prevent the possibility of any bundles passing between and not have their bands cut.

The distance between the front end of the carrier and the traveling rake O forms a reservoir in which to hold a quantity of grain. The yielding board Q, having the office of pressing it against the rake which only takes off a given portion, it being the amount the length of the teeth will grasp and move.

Should the quantity of grain become excessive, the yielding board Q will be depressed and a connecting mechanism throws the carrier out of gear and stops its travel until said board reaches its normal position again.

The size of the throat may be varied by sliding the fingers R, and retained in position by the thumb nut W and washer U.

Figure 8 represents a class called crank feeders.

The bundles are placed on the sheaf carrier, which deposits them on the oscillating bottom or feed board, where they are acted upon by the band-cutting knives

above. The knives are operated by a multiple crank which gives the forward part of the bars holding the knives a circular motion, and the rear end an angular parallel motion. This action cuts the bands and tends to elongate the bundle towards the cylinder; the notched

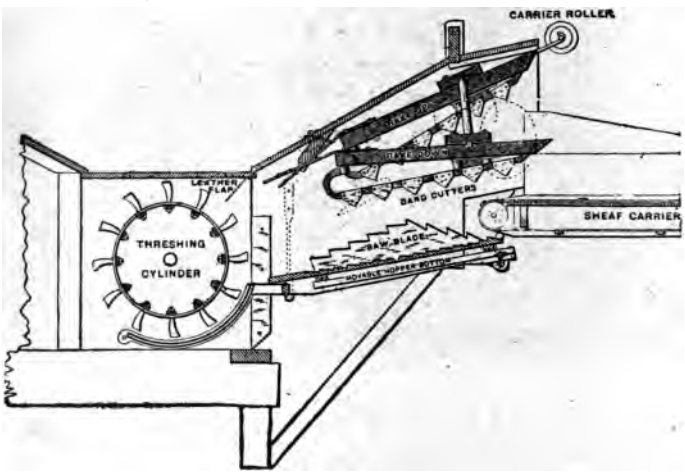


FIGURE 8.

pieces below tending to retard the bottom portion of the grain somewhat, while the knives cut and loosen from above.

The cranks are constructed so the knife bars balance, as they revolve, by being set opposite each other.

Figure 9 shows a sectional view of a modern steel thresher equipped with all the latest improvements.

Feeders for Headed Grain.—In Washington, Oregon and California the grain is headed and stacked in ricks. These grain ricks are about 110 ft. in length, arranged

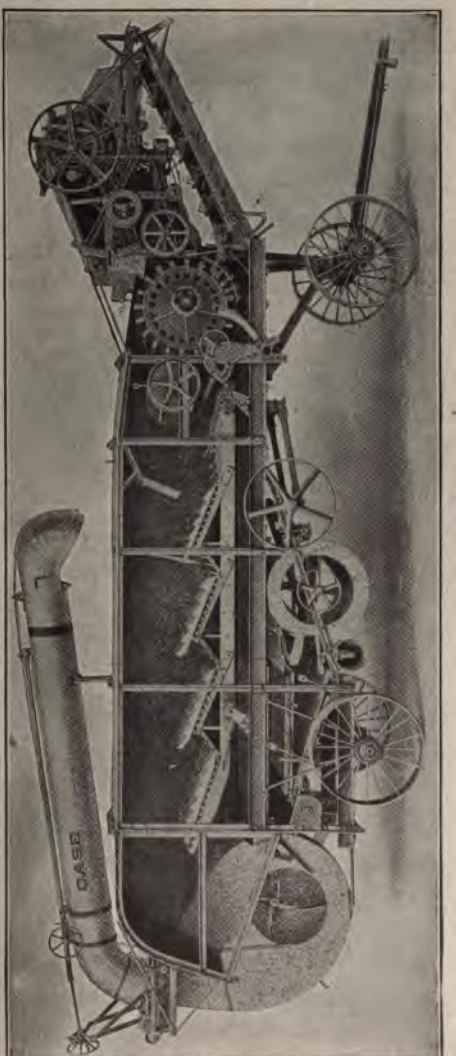


FIGURE 9.

in groups of four—two on each side of a track wide enough to permit the derrick wagon to pass between them.

This derrick wagon consists of a platform about 14x20 mounted on low trucks and supporting a derrick to carry the rope sheaves for the fork cables, which are usually ⅜ in. in diameter and 120 ft. long.

Four derrick forks are used, two forks and two teams being required for an engine outfit. The end of the

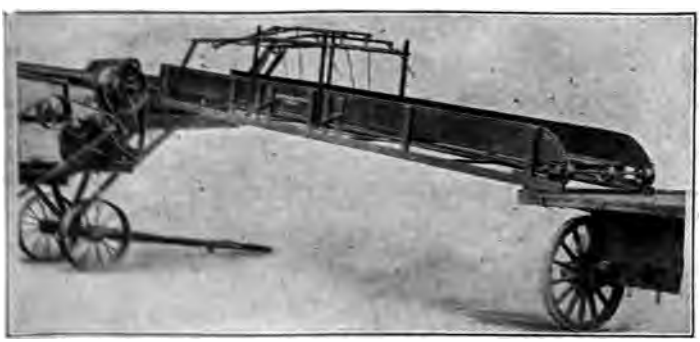


FIGURE 10.
Feeder for Headed Grain.

side carrier of the feeder rests on the derrick wagon, the threshing machine being set alongside of the stacks, so that the whole side is free for taking away the threshed grain.

Where the grain is threshed directly from the headers without stacking, the end of the long carrier is usually placed on the ground over which a canvas is spread. If the derrick is used, the header wagon boxes are ar-

ranged so that the cable hooks to them and dumps the grain into a net which is spread in the boxes before they are filled. Often, however, the header wagon drivers pitch the headings into the canvas spread on the ground.

One of these feeders for headed grain is illustrated in Figure 10.

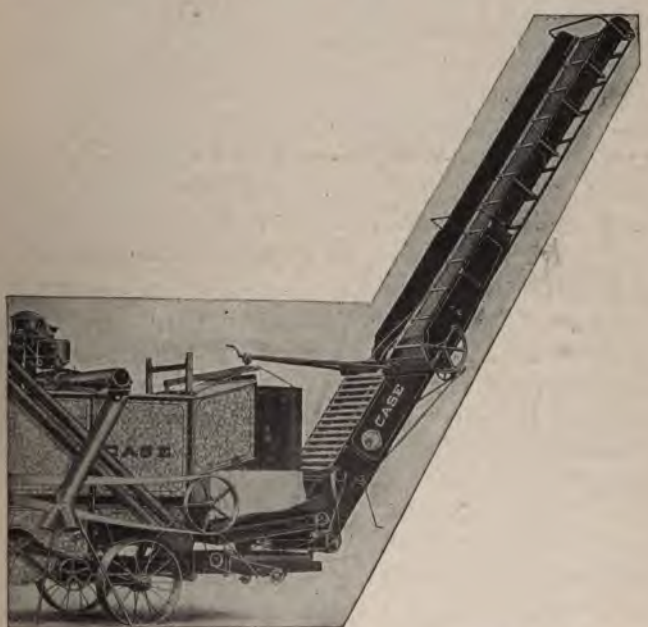


FIGURE 11.
Stacker Drive and Elevation of Carrier.

Wind Stackers.—The wind stacker carries the straw to the stack by means of a strong blast of air passing through the tube or pipe into which the straw is fed.

The air blast is supplied by a fan operated by belt. Considerable power is required to drive this fan, but this type of stacker possesses the advantage of being able to throw the straw farther from its outlet than the carrier stacker can. Another advantage in its favor is that it requires no extra effort to set it, when commencing a new setting of stacks, or in moving the machine after the stacks are completed.

Carrier Stacker.—Figure 11 is an elevation of this type of stacker. The main rake passes only through the upright and outer sections, and runs loosely and as easily as on a straight stacker of the same length. There are pulleys at the top of the upright section as well as the bottom, and all of them are drivers. The sheet-iron straw guard prevents the straw, as it leaves the machine, from being scattered by the wind. It is fitted wtih canvas curtains around the lower edge, which prevent littering, even with a strong side wind. By changing the position of the trip pins the stacker can be made to swing in any desired part of the half circle irrespective of elevation. It is driven from the threshing machine cylinder, and the belt runs free of all parts of the machine or stacker without the use of idlers or guides. It is always locked in position and the slipping of a dog will not cause it to fall. The crank for folding it is at the right for the operator standing on the ground.

The folding device is also the raising device, and is both simple and safe. The upright section is hinged to the lower end, and is raised or lowered by means of the screw support on top of the threshing machine.

Handling the Threshed Grain.—There are various styles of weighers, sackers, measures and wagon loaders in use for handling the cleaned grain as it comes from the

machine. One type weighs the grain and registers the number of bushels delivered. This is shown in Figure 12. There are also those that measure the grain instead of weighing it, keeping a record of the amount on a suit-

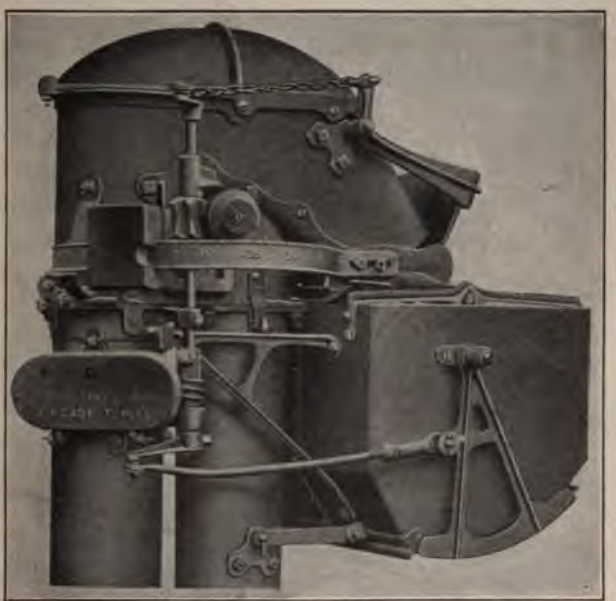


FIGURE 12.

Head of Regular Weigher, Showing Scale Beam, Tallier and Hopper.

ably arranged tallier. Then there is the common short sacker, a very handy and common means of getting the grain sacked, requiring one man to operate it. Lastly comes the wagon-loader, an arrangement that delivers to either side of the machine without any device for recording the quantity handled.

Operation.—In operation, the threshing machine, the same as any other machine, will do the best work when properly managed.

Scarcely two fields of grain have grown, ripened and been cut and handled the same. One may be in a condition to shell from the straw easily, while in another the kernels may cling to the chaff or heads so as to make it almost impossible to dislodge them. One stack of grain may be brittle and cut up, another may pass through without breaking up much. One kind may be stiff and stubborn, another soft and pliable. One lot may have many blades or leaves on the stalks, another only the plain stalk and head. One kind may have a light fluffy chaff and dense heavy kernels, another with the chaff heavy and filled with sap and the kernel as light as the chaff. Some fields are filled with weeds and foreign matter which the machine is expected to distinguish and separate from the grain.

Then again some conditions require more power than others to drive the machine. Some days are bright and sunshiny, others damp and foggy. Some warm or hot, others cold. There may be a hard wind blowing or none at all, each condition affecting the machine in a different way. The experienced operator is expected to meet all these varied conditions and save every kernel, and clean the grain perfectly, and do many other things well nigh impossible. But the man who understands the machine and its workings best, will come the nearest to perfection in the operation of the same.

The cylinder should receive special attention and be kept in good condition. If it is too much out of balance it should be taken from the machine and set on straight edges and put in balance again by inserting counterbal-

ancing weighs on the light side. The boxes should not be run too tight as it consumes a large amount of power to overcome the extra friction.

The teeth should not be permitted to become so worn and rounded as to retard the straw from entering the cylinder freely. Part new teeth divided equally around and along the cylinder, will assist in the suction of the straw, and thresh clean also.

The cracking of grain is usually caused by one or more teeth running so near the concave teeth or bottom as not to permit a whole kernel to pass, and by being wedged between the teeth the kernel is cracked or broken. Only sufficient concave teeth should be used to retard the straw long enough in its passage through the cylinder to allow all the kernels to be loosened. In threshing oats, two rows are usually sufficient. In sections where flax is grown it is a good plan to have a concave especially designed, with the teeth closer together, and the cylinder running at a high speed. The same conditions apply to barley. The grate back of the concave should be raised at the rear side enough to permit the stream of straw and grain flowing from the cylinder to strike its face at a slight angle. The beater should be in a position for the straw to pass it without changing the course of the straw too much, that is, it should be in such a position that the straw coming from the cylinder will not strike it near the center, as it would then have to change its course to pass under or over the beater, as the case may be.

When the straw passes under, the beater should be only low enough to reach the straw sufficiently to keep it moving.

In the scheme of separation the first essential feature is to have the cylinder leave the straw as near whole as

possible and have it threshed clean of kernels. The nearer whole the stalks are the more freely will the kernels fall out, as it will not pack together so much as if cut and broken up.

In some cases the stalks are heavily loaded with leaves that break loose and cut up forming a homogeneous mass in which the kernels are lodged and retained.

Oats in some cases are difficult to separate. In some sections of the country the rust forms on the stalks and leaves before being harvested. It usually leaves them very brittle, and the kernels blight, making them light. The rust on the stalks has a certain clinging roughness that makes them adhere to each other, and tends to retard the action of the rack or raddle in moving them about among each other, they having a tendency to move along in a continuous mass. In such cases all that can be done is to adjust the machine to the best advantage, run with a full motion and regulate the amount being fed accordingly.

In threshing rye, which is usually very easily separated on account of the stalks being stiff, comparatively little chaff and leaves are found to retard separation. In some cases the straw is so fluffy and loose as to prevent it being worked back fast enough by the separating devices, causing the body of the machine to choke and fill up. This may be remedied somewhat by inserting more concave teeth to cut the straw up.

The Check Board in vibrating machines can sometimes be weighted to advantage, which has a tendency to pound the straw down and compress it, giving the table a better chance to handle it. The check board can be weighted by fastening a piece of wood or iron to its back and upper side, running it lengthwise, and securing it by bolts or screws.

The Shoe, or cleaning mill, should receive special study by any one who intends to make threshing a success. Though a very simple appearing device, it has many features that are not generally understood. The large variety of arrangements of the different parts prevents this book from going into the details of every machine, but it will deal with them in a general way that is applicable to all.

The Motion of the shoe is varied in the different machines, in some as short as ⅝ of an inch, up to 4 ins. in others, though there is not so much difference in the motion of the upper sieve or chaffer. In most machines it is from 2 to 3 ins. The following rule will be found nearly correct, viz.: the shorter the stroke the more vibrations per minute, the longer the stroke the less the number of vibrations per minute.

The Speed should be only strong and quick enough to throw the grain but slightly at the top finish of the stroke, if more than this, it is too strong and will carry or throw the grain, and a part of it will pass out with the chaff. If the motion is not strong enough to cause the grain to leave the upper surface of the sieve slightly at each stroke, the result is the meshes become filled with grain and chaff, the sieve or chaffer becomes choked and loaded up to such an extent as to allow but very little to pass through. If the mechanism is such that the upper part of the stroke is the more strong and quick leaving the lower end of the stroke slow and mild, all the better; as the upper part will do the throwing and agitating, while the slow part of the stroke will give the sieve time to come to rest for an instant, permitting the kernels to fall through much better.

The Boxes and connections that operate the shoe should

be kept in good order and not be permitted to get loose, as the loss of motion causes a pounding that jars the sieve causing it to spring and tremble, greatly interfering with the free passage of the kernels.

The Blast should come in for its share of attention. Much depends upon it to accomplish good work and when once mastered and controlled it is a very obedient servant. But few changes have been adopted in the construction of the fans since they were first used in the separators. They have faults as well as virtues; they do not always send the proper amount of blast just where intended or needed most.

There is a great difference in the condition of the material coming to the shoe to be handled at different times, and in different sections of the country. In parts of the country where spring wheat is raised there is much more work required of the shoe, there being more chaff; and the straw being stiffer and harder to thresh, breaks up much more than that of the variety known as winter wheat raised in other sections.

Belts.—The success of a machine depends largely upon the working of the belts. Their proper care and management is of importance. The material should be of the best quality.

Leather belts should always be run with the grain or smooth side to the pulley, as they will run easier, transmit more power and last longer. They will run easier because the flesh, or rough side, by being on the outside will expand more easily and adjust itself to the curve in passing around the pulley, which also has a tendency to add to the life of the belt. The smooth side will transmit more power because it brings more surface in contact with the pulley. They should be run only tight enough

to perform the work without slipping, for whatever power is consumed in slipping is lost. If a belt is permitted to slip it will have a tendency to partially run off of the pulley, and will also soon wear out the lacings.

If belts become dry and brittle they should have a dressing of neatsfoot oil with a very little resin mixed in it. Do not use enough resin to leave the surface of the belt sticky. A belt that is pliable will transmit more power than if dry and hard.

Rubber belting is also used quite extensively for some purposes, and when of the best grade is very economical, as its first cost is less than that of the best grades of leather.

Chain or link belting is used, and in some places is preferable to any other. It never slips or runs off, nor does it ever come unlaced. When link belting is used it should not be run too tight, as it causes a trembling or jarring vibration as each link passes on to the sprocket.

Babbitting Boxes.—With a little care and practice any one of ordinary ability can babbitt boxes.

First remove the old babbitt and clean the boxes well, to get them free from grease and dampness, as the gases when heated will cause the babbitt to blow out. Bolt the boxes in place with shimming (pieces of pasteboard) between the halves to allow take up for wear. Hold the shaft in place at the center of the box by inserting a narrow strip of leather around the shaft at the end of the box, then with clay moistened to the consistency of stiff dough thoroughly seal up all openings to prevent the liquid metal from running out. Place a wooden stick in the oil hole and plaster up, leaving the top flaring to pour the metal in. After all is in readiness remove the stick with

care to prevent any clay from being broken loose and falling into the box.

In preparing the shimming between the boxes see that the edge of the shimming comes against the shaft, in order to separate the metal in the two halves. Cut two or three small notches in the shimming about ⅛ in. deep and ¼ in. long to allow the babbitt to run in and fill the lower half of the box.

To be successful the babbitt metal should be at about the temperature required to burn a piece of wood. To test it insert a stick into the melting metal occasionally, and when it gets hot enough to make the stick smoke or turn black it is of the right temperature. When pouring do not stop until the box is filled, as the metal chills very quickly and will not unite when fresh metal is poured in. The metal should be poured in as fast as it will run through the opening to insure its filling the lower half.

If the lower half should not fill properly enlarge the openings in the shimming between the halves of the box and try it again. After pouring, remove the clay and break the box apart by driving a cold chisel between the halves, then dress off the points formed in the notches of the shimming.

Relieve the shaft a little by scraping some of the babbitt metal away from the inside of the box, removing the most near the inside edges; also put in an extra piece of shimming, as the box would be too tight and would heat if left as babbitted.

If a stick is inserted into the oil hole as soon as the metal is poured, it will form an oil hole and save drilling or punching same out.

Lubrication.—In selecting a lubricant, attention should be given to the conditions under which it is to be used. In [illegible] dry weather a much heavier oil can be used than

in cold weather. Mineral oils are usually to be preferred to animal or vegetable oils. An excellent lubricant is made from petroleum and comes in the shape of a solidified oil or grease. Special cups are made for it.

A good grade of oil for general purposes is what is called black or crude oil. It is a mineral product with all the light oils removed, and comes in different grades of density. The heavier qualities can be used in warm weather to advantage, while in colder climes the lighter grades will be found to run more freely, and not thicken as readily.

Getting Ready.—If the machine is one that has been in use the year before, it should be put in good condition before the time announced to commence threshing by going over it and seeing that every piece is in proper condition to maintain a fall's run. See that the boxes over the entire machine are properly adjusted and any worn ones set up. If too much worn they should be rebabbitted. A shaft should not be so loose in its bearings as to permit much rattling or moving back and forth.

All boxes where the shaft is compelled to produce or withstand a vibrating motion should be kept in good condition and not be allowed to get loose at any time, as the least play will permit the shaft to pound at each vibrating stroke, causing the shaft to wear flat. It will also prevent the part from being oscillated or vibrated smoothly and easily, and may interefere with its performing the functions intended.

All vertical oil cups should have a piece of clean waste inserted to retain the oil and keep out the dust and dirt. See that every belt is properly laced and of the right tension. If too tight, instead of over-straining it in putting it on, it is much the better plan to relieve it a little by

letting out the lacing, and then take it up when the belt has stretched. A little neatsfoot oil and resin will, if applied to a belt, soften it and greatly prolong its life. If the frame of the machine is warped it should be gotten in line again. Straw rakes and raddles should be put in good condition. The tool box should be well equipped with all necessary tools, together with assorted sizes of bolts, screws, rivets, etc. If the machine is a new one, it should be put in its proper place and thoroughly inspected and all nuts tightened. The machine should be run empty for a time before assembling the crew.

The Crew.—The duty of the manager is to have charge of the machine and crew and see that everything is operating properly, arrange the work so it may be done in the most expeditious manner, economize time and expense to accomplish the most with the least outlay of labor; look after the welfare and comfort of the crew, and see that each one performs the tasks assigned him. Much depends upon him for the success of the machine.

To make the machine work properly and do its best it is necessary that each man should perform his part and it belongs to the manager to see that this is done and should be entirely under his control.

The feeders should be sufficiently well acquainted with the machine to be able to work in harmony in order to aid in the successful progress of the work. The usual practice in hand feeding is for each to feed a given time or a given amount of grain when he is relieved by the other feeder. The feeder is the one depended on to regulate the amount being threshed and much depends upon him to make the machine do a good day's work.

The feeding should be even and continuous and as near the same speed at all times as is practicable, that

the crew may become accustomed to the amount of grain and straw to be handled, and be able to judge the amount of labor required of them. The motion and working of the machine should be kept well in mind and be noticed and corrected as soon as not right. The motion of the one feeding should be suited to the kind and conditions of the grain being threshed. The more the straw is divided up and spread out the less power is consumed in passing it through the cylinder.

The pitchers are depended upon to get the grain to the machine in quantities as fast as needed and in a manner to facilitate work. There should be enough pitchers provided so the machine will not have to wait for grain or run partly empty, as it necessitates the remainder of the crew to be partly idle, and curtails the earnings of the machine.

It is better practice for each man to keep his particular position on his own side of the machine during the time he is with it. He then becomes accustomed to moving the bundles in a certain way on that side, while on the other side the position would be reversed.

The straw crew are to take care of the straw as fast as delivered from the carrier.

It will be found to be as easy to form and build a good symmetrical stack as to simply push the straw back, without any reference to the form of the pile.

The straw will have to be moved a less distance by beginning the stack well up toward the machine so the stacker will drop the straw nearer in the center of the stack, than if commenced back so far that the stacker comes only to the edge, as then it will have to be moved clear across the distance of the stack. To keep well the center should be tramped more. The outside portion

will then settle more, causing the straws to incline downward at the outside, making a better watershed.

Setting the Machine.—Some put great stress on how their separator is set when ready to work, though they can not always tell just why it must be that particular way. Some set one end a little high, others would set the same machine differently and contend it was nearer right. These ideas are usually gotten in threshing some particular setting which went extra good, other conditions being favorable, and not entirely understanding the features and functions of all the parts of the machine, they conceived the notion that it must be set just so. It is not to be understood by this that it makes no difference as to how the machine is set, but it would be hard to explain the reasons why an inch either way would make any material difference.

Sometimes with the vibrating rack, if the straw is loose and fluffy and the stroke is not sufficiently long and sharp to work it back fast enough to separate well, the separator may be lowered at the rear end to advantage as the straw will work off a little faster than if higher.

The separator should be near enough level sideways to prevent the grain from shaking down to one side of the sieves. If the grain is blowing over on one side, it can sometimes be remedied by lowering that side of the machine, causing more grain to pass there, thus partly retarding the blast.

Moving.—During a fall's run from one-fourth to one-half of the time is consumed in moving and setting, therefore a thresherman should study well to attain the most expeditious plan to tear up and move.

All should work together to clean up and be off to the

next setting without delay. The manager and engineer should see that everything possible is loaded, the horses if used, gotten ready to hitch on, so that as soon as the belt is thrown off and rolled up everything is ready to go.

If convenient, the setting should have been visited and the manager should see that it is properly cleared of all rubbish or stones that may be there, and decide which way the straw is to be thrown.

A place should be provided for every article to be carried along. Each oil can, spade, bar and box should have its particular place. Commence to load up before the grain is all cleaned up, putting each piece in its place. By using a regular system the time consumed can be reduced to the minimum, and much labor saved. The engineer will have his engine properly oiled and greased and everything in order and ready to travel at once as soon as the belt is thrown off.

CHAPTER II.

TYPES OF THRESHING MACHINES.

In order to bring out more clearly the characteristics of modern threshing machines, several of the leading types of machines are described in detail and illustrated in the following pages.

SAWYER-MASSEY THRESHER.

Figure 13 is a semi-sectional view of the Sawyer-Massey "Great West" thresher. These machines are built with either a 12- or 16-bar cylinder. The 16-bar size has been added after a series of experiments extending over a number of years, which prove it to be the most suitable size for a large cylinder, and one that has given the best satisfaction. As shown in Figure 13, there is sufficient grate surface to insure perfect separation. Figure 14 shows a front view of the 16-bar cylinder. The pulleys are of large diameter and of sufficient width of face to prevent belt slippage.

Concaves.—Figures 15 and 16 illustrate the concaves and grates. Figure 16 shows the large number of combinations that can be made with this equipment, depending upon the number of teeth required in the concaves according to the condition of the grain.

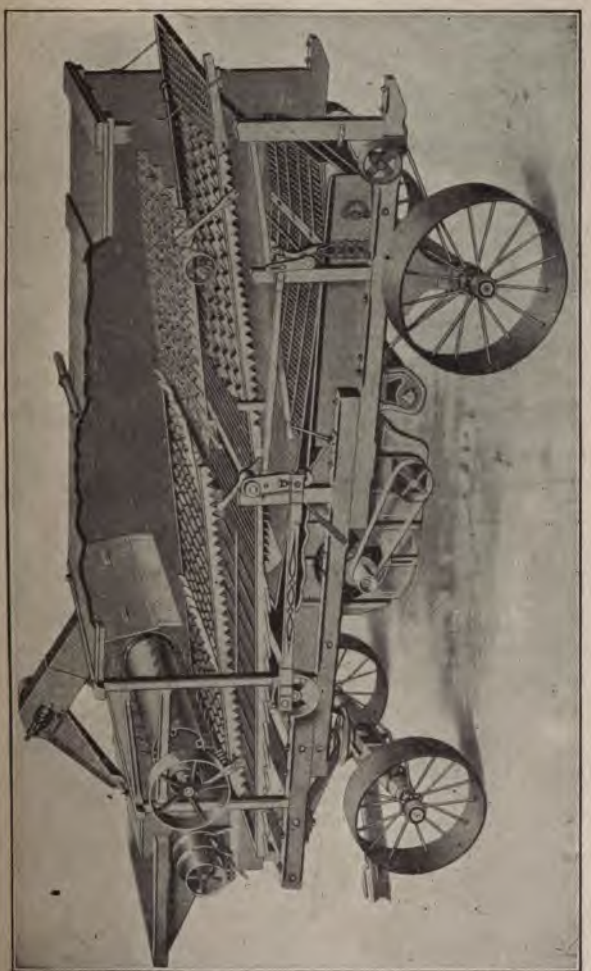


FIGURE 13.—
Showing Internal Construction of Sawyer-Massey "Great West" Thresher.

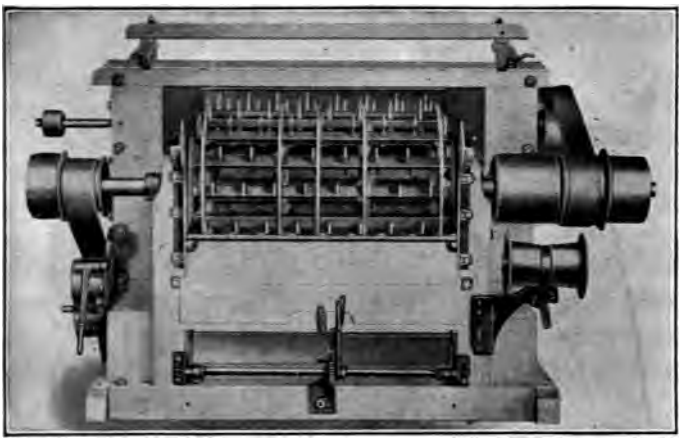


FIGURE 14.
Front View of 16-Bar Cylinder.

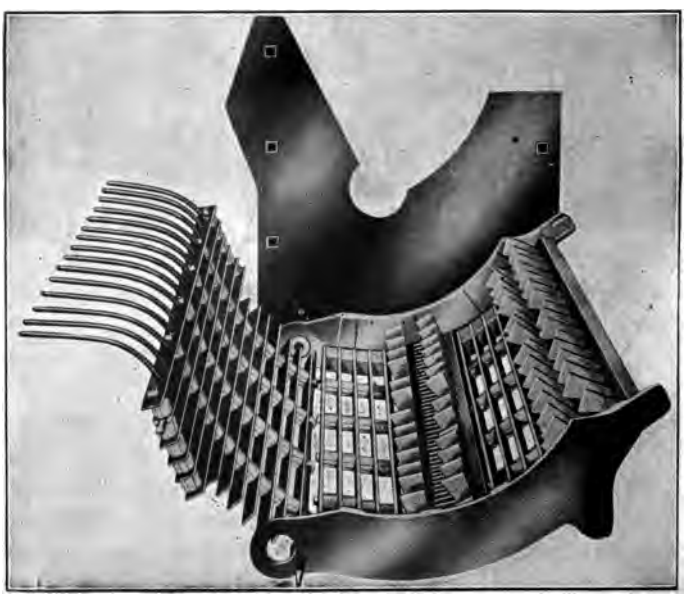


FIGURE 15.
Concaves and Grates for "Great West" 16-Bar Cylinder.

The distance between the concaves and the cylinder itself can be regulated with ease and rapidity while the machine is in motion to suit all kinds and conditions of grain.

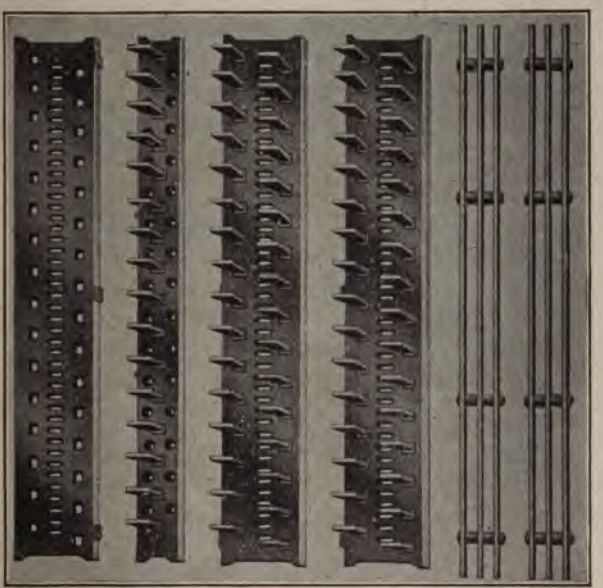


FIGURE 16.
Showing Details of Concaves and Grates.

Belt-Tightener.—Figure 17 shows the belt-tightener that is used on this thresher. This device permits the use of an endless belt for driving the agitators. The cylinder boxes, one of which appears in Figure 17, are

well babbitted, and they are equipped with grease cups and oilers on the bottom.

Feeder.—Figure 18 illustrates the No. 2 feeder, which has several excellent features: It is made of heavy

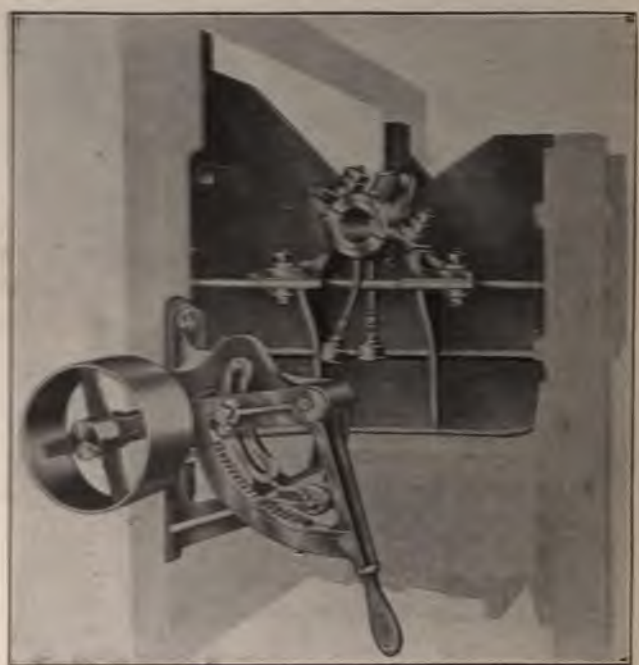


FIGURE 17.
Cylinder Boxes and Belt Tightener.

steel; light running, taking very little power; delivery of grain to the cylinder at the proper point to save power and assist clean threshing; large pulleys, insuring

sufficient belt surface; convenient accessibility of working parts when running, for oiling, etc., no crankshafts or eccentrics, all straight line shafts, perfectly balanced and noiseless in action; a retarder that works perfectly and does not permit slugging, no matter in what condition the grain is; a distributing wing beater with teeth similar to those in the threshing cylinder of the separator.

FIGURE 18.

The New Sawyer-Massey Feeder No. 2.

The sheaves are up-ended just as they reach the cylinder and go down between the cylinder and concaves vertically, head first. The retarder being in the proper position and speeded correctly, holds the under side of the sheaf from slipping into the cylinder until the top side has been gradually combed off, when the retarder relieves the balance. This operation continues constantly while grain is being fed to the machine.

NEW RACINE THRESHER.

Figure 19 is a view of the New Racine thresher, built by the International Harvester Co. The steel cylinder is shown in Figure 20.

The cylinder shaft is made of heavy machine steel,

FIGURE 19.

Left Hand Side of New Racine Thresher—48, 52, and 56-inch Rear —with Feeder, Wind Stacker, and Weigher with Swinging Conveyor.

and runs in extra long bearings of the ball-and-socket self-aligning type. The best quality of frictionless babbit, accurately scraped and snugly fitted to the ... gives a maximum saving in the operative power

at this point. Oil wells of large size with hinged covers supply a steady flow of oil. The cylinder is supported within a heavy cast iron frame which is securely bolted to the framing timbers and sill of the thresher body. The iron sides of this frame are securely braced by steel rods.

Tooth Bars.—The tooth bars are so securely connected to the heads of the cylinder that practically a one-piece mechanism is formed. The teeth are fastened to the

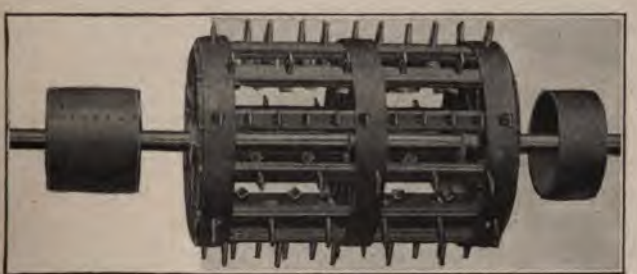


FIGURE 20.
New Racine Bar Cylinder Used On the Larger Sizes.

tooth bars and held on the inside in such a manner that it is practically impossible for them to work loose. Bent teeth can be straightened with a tooth set furnished with each machine.

Teeth.—Figure 21 illustrates the steel tooth used in these threshers. The cylinder teeth are made from a special grade of steel and, without being brittle, are sufficiently hard to withstand successfully all the wear and hard work to which they may be subjected. They are secured to the cylinder by nut and lock spring washers

FIGURE 21.
Cylinder Tooth.

and the holes fit the shanks of the teeth perfectly. The teeth are therefore held so rigidly in place that they really become a fixed part of the cylinder. To insure easy feeding, proper attention has been given to the angle at which the concaves are set and to the shape of the teeth. One very important point is that the cylinder

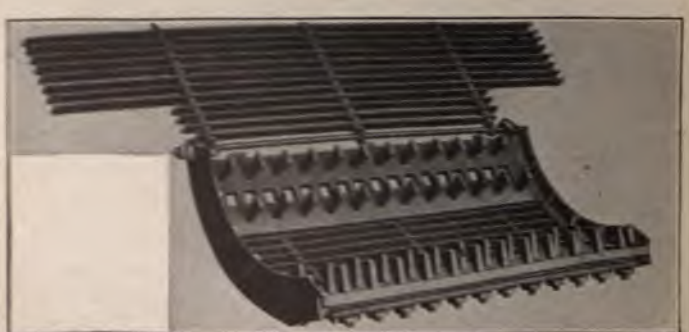


FIGURE 22.
Concaves and Grates.

teeth and concave teeth are interchangeable, being of one size and shape.

Concaves and Grates.—These threshers are fitted with space for three concaves. See Figure 22. All machines are equipped with two concaves filled with teeth and one without teeth, and with two steel concave grates.

FIGURE 23.
Steel Beater.

This equipment gives all the range that is necessary to thoroughly thresh the grain from the straw under various conditions. The teeth are of heavy design and the steel strap through which the shank of the tooth passes

and is bolted, insures strength and reduces the liability of breakage to a minimum. Directly behind the concaves is a grate which extends rearward and upward under the beater. Here also large openings are made so that separation as soon as possible can be accomplished. About 95 per cent of the grain is separated just back of the cylinder. By allowing a liberal grate area, much of the grain that would otherwise mix with the straw is saved.

Beater and Check.—The condition of the straw after passing through the concaves is such that with proper handling the best results can be secured with the winged beater, which is one of the best and most effective devices known for its purpose. The action of the beater (see Figure 23) is similar to that of a flail as it beats the kernels of the grain down through the thin layer of straw onto the conveyor.

Just back of the heater is a sheet steel check flap to keep the stray kernels from being thrown out at the rear of the machine and to hold or retard the movement of dry and brittle straw. The size of the opening can be easily adjusted from the outside simply by raising or lowering this check flap.

Ruth Feeder.—The Ruth feeder feeds the grain without slugging the cylinder or loosening a tooth. Every thresherman knows that slugging the separator causes a certain amount of grain to be lost in the stack, besides breaking the cylinder teeth and concaves, burning expensive belts, and shortening the life of the threshing outfit. Where the Ruth feeder, Figure 24, is employed, every band is cut and every bundle thoroughly loosened up and pulled apart before it can pass to the separator cylinder.

The Pickering governor used on the Ruth feeder is

very sensitive. Whenever the feeder cylinder falls below the proper speed, the governor operates the trip lever which stops the raddle until the mass of grain is disposed of by the feeder cylinder and retarder. The governor

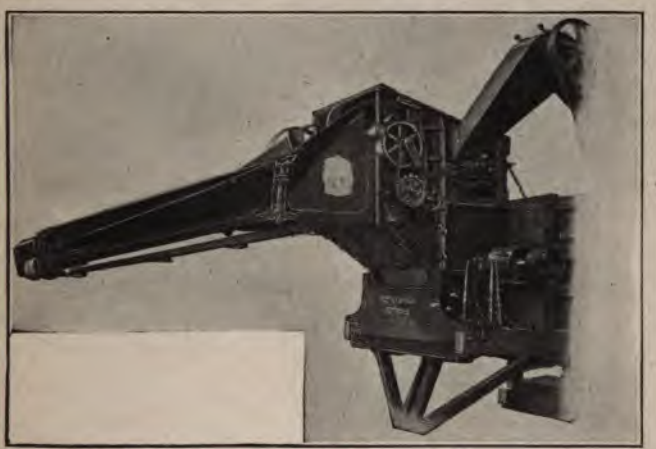


FIGURE 24.
The Ruth Feeder.

then permits the raddle to run. The feeding of the grain to the separator does not stop, but continues in an even, steady flow.

BUFFALO PITTS THRESHER.

Figure 25 shows a view of the "Niagara Second" thresher built by the Buffalo Pitts Co., Buffalo, N. Y. The particular feature of merit claimed for this thresher is the method employed for the separation of the grain

FIGURE 25.

The Niagara Second Steel Frame Thresher Equipped with Feeder, Buffalo Pitts Aircraft Cleaners Wind Stacker, Weigher and Bagger.

and straw. After the grain and straw have passed the threshing cylinder, the straw is first operated upon by the second, or separating cylinder.

A view of the two cylinders is shown in Figure 26. A separating cylinder when properly located and adjusted in its relation to the threshing cylinder, is a very effective device for separating the grain from the straw.

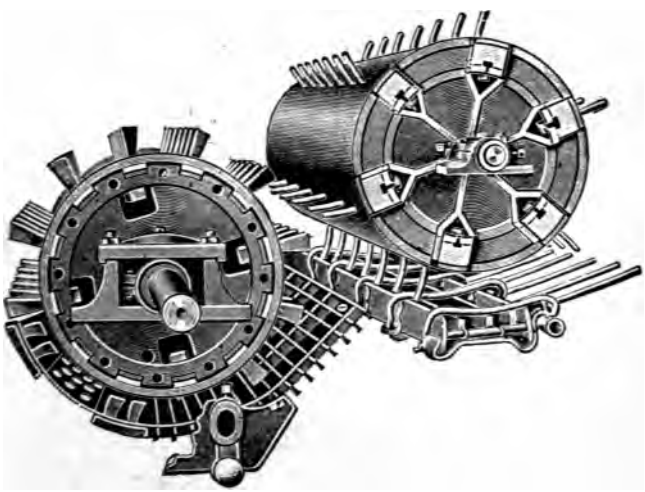


FIGURE 26.

Threshing and Separating Cylinder and Grates.

As the grain leaves the threshing cylinder, a separation of the short straw and grain from the long and heavy straw is effected. The short straw and grain are carried to the lower straw rack, Figure 27, and the long straw to the upper straw racks, and in this operation is obtained a duplex effect. The mass is thus divided into two distinct bodies, and is handled on double straw racks. The

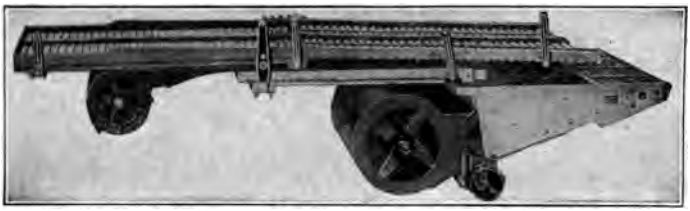


FIGURE 27.
The Lower Straw Rack, or Chaffer, and Auxiliary Fans.

upper straw racks are so constructed and operated, that they tend to move the upper half of the long straw faster than the lower half, thus tearing the straw apart and allowing the remaining grain to fall through to the lower straw rack. The lower straw rack at the same time is operating on the short straw and grain, with the assistance of the auxiliary fans and grain pan, in such a manner that only the grain and chaff are delivered to the shoe for final cleaning.

Teeth.—Figure 28 shows the T-6 tooth together with

FIGURE 28.
Buffalo-Pitts T-6 Cylinder Tooth.

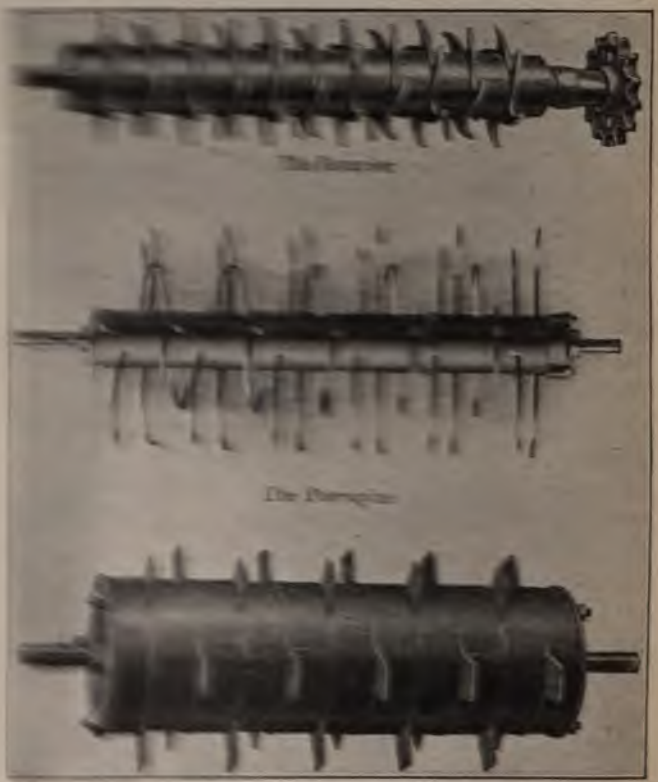
the nut and spring lock washer. The same tooth is used in the cylinder bar and concaves, and but one bar and head tooth, so that for the cylinder and concave only two kinds of teeth are used, namely T-5 and T-6. This does away with the large variety of teeth usually necessary for a complete set.

Buffalo Pitts Steel Feeder.—The action of this feeder, a view of which is shown in Figure 29, is as follows:

FIGURE 29.
Interior View of the Buffalo Pitts Steel Feeder.

The grain is carried under the rapidly revolving knives, which cut the bands and act as a stripper from the top, while the rapidly revolving feeder cylinder carries the grain forward from the bottom. The grain is thus delivered to the retarder, which holds it at the bottom while the porcupine, which acts as a storage, will feed it to the cylinder evenly, keeping the cylinder full.

Figure 30 shows the retarder, the porcupine and the



The Feeder Cylinder.

FIGURE 30.

feeder cylinder. The governor, or feed regulator, acts independently of the speed of the threshing cylinder, and stops the carrier retarder and porcupine, thus holding the grain until the cylinder is ready to receive it. The tailings are delivered through the side of the feeder directly in front of the threshing cylinder, and are carried in by a slowly revolving fan, which eliminates the throwing of the grain out through the front of feeder.

MINNEAPOLIS STANDARD SEPARATOR.

This machine, a view of which is presented in Figure 31, is built by the Minneapolis Threshing Machine Co., in sizes from 24x42 to 40x62 ins.

The Feeder.—A good idea of the construction of the feeder attached to this thresher may be obtained from Figure 32. It is equipped with an automatic governor and fish-back feeding pans. It has a long, heavy chain carrier with a high center board to keep the bundles in line while they are being carried to the band knives. The carrier is held in position by two adjustable rods which also hold the carrier when folded under the feeder. The knife bars are driven by a heavy crank shaft, with two of the knife-bars directly opposite the other two, and perfectly counterbalanced, making the feeder run smoothly and quietly. There are four of these knife bars with knives on each side. The feeder mechanism is driven by a leather belt equipped with a tightener, by means of which the belt may be loosened entirely and the feeder stopped whenever desired.

The opposite end of the shaft has a friction governor on it, which not only keeps the carrier and feeding-pan

from working until the cylinder has attained the proper speed, but also controls the amount of grain carried to the cylinder while threshing. The speed of the governor may be varied at the will of the operator by interchangeable gears.

Tilting Device.—This device gives the operator free access to the cylinder and concaves in order to do any work required about the cylinder. The feeder can be tilted in

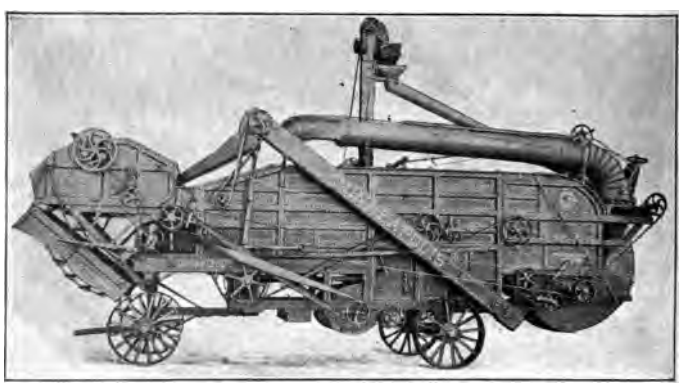


FIGURE 31

The Minneapolis Standard Separator. Feeder, Dakota Weigher and Minneapolis Gearless Wind Stacker.

a moment's time by throwing off the main belt and loosening two hooks on either side of the brackets.

Crankshaft.—This shaft works in pivoted boxes, which are adjustable, and may be raised or lowered to suit large or small bundles.

There is a set of auxiliary fish-back feeding pans, operating at high speed and hanging on malleable iron hang-

Concaves and Grates.—The concaves and grate used in this separator present a large separating surface and insure a great amount of separation at the cylinder.

After the straw passes through the cylinder, it is carried over a slatted iron grate directly back of the concaves, causing the greatest separation to take place at this point, allowing the grain and chaff to fall through onto the grain pan.

The Grate is arranged so it can be raised and lowered to suit the conditions of the grain, while the machine is in operation. The six-wing beater is immediately in the rear of the cylinder. It is so constructed that it stops the flying kernels and spreads the straw on the rack.

The Upper Straw Rack or separating table is equipped with a series of lifting fingers which keep up a continual and thorough agitation of the straw, allowing the grain to pass through the slatted table onto the lower pan.

The Pickers are placed immediately behind the apron and are a very valuable and effective means of separation. They work above and into the straw and prevent it from bunching. Reaching forward, they assist in carrying the straw to the rear and release any grain remaining in the straw.

The Beater is immediately in the rear of the cylinder, and revolves in the same direction. Being large and iron covered, it stops all flying grain, while the construction is such as to spread the straw toward the sides of the separator.

The Straw Rack is fastened to the upper end of the rocker-arm and the galvanized steel grain pan to the lower end, and it is so arranged that when the straw rack travels backward, the grain pan travels forward, thus making

it evenly balanced, and making the separator run much lighter

The Shoe is an end-shake, and hangs on wood pitmans, on the outside of the separator. It is driven from the center of the crankshaft, and all connections to the shoe are on the outside of the machine, where they are readily accessible and can be easily taken care of.

Above the grain sieve is another chaffer, which is fastened in the shoe, and when the chaffer attached to the grain pan moves backward, the one in the shoe moves forward. This provides a double chaffer over the grain sieve. The grain, when finally separated from the straw and chaff, and cleaned, is delivered from the shoe to a grain auger, and thence to the weigher, where it is measured and weighed, and dumped into sacks.

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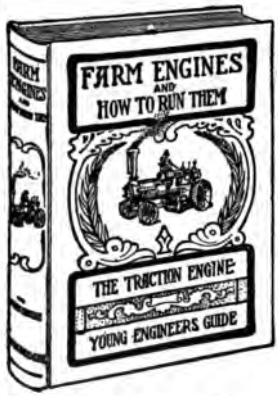

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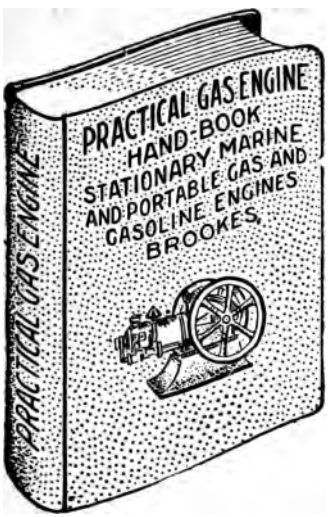

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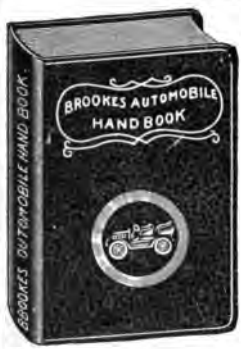

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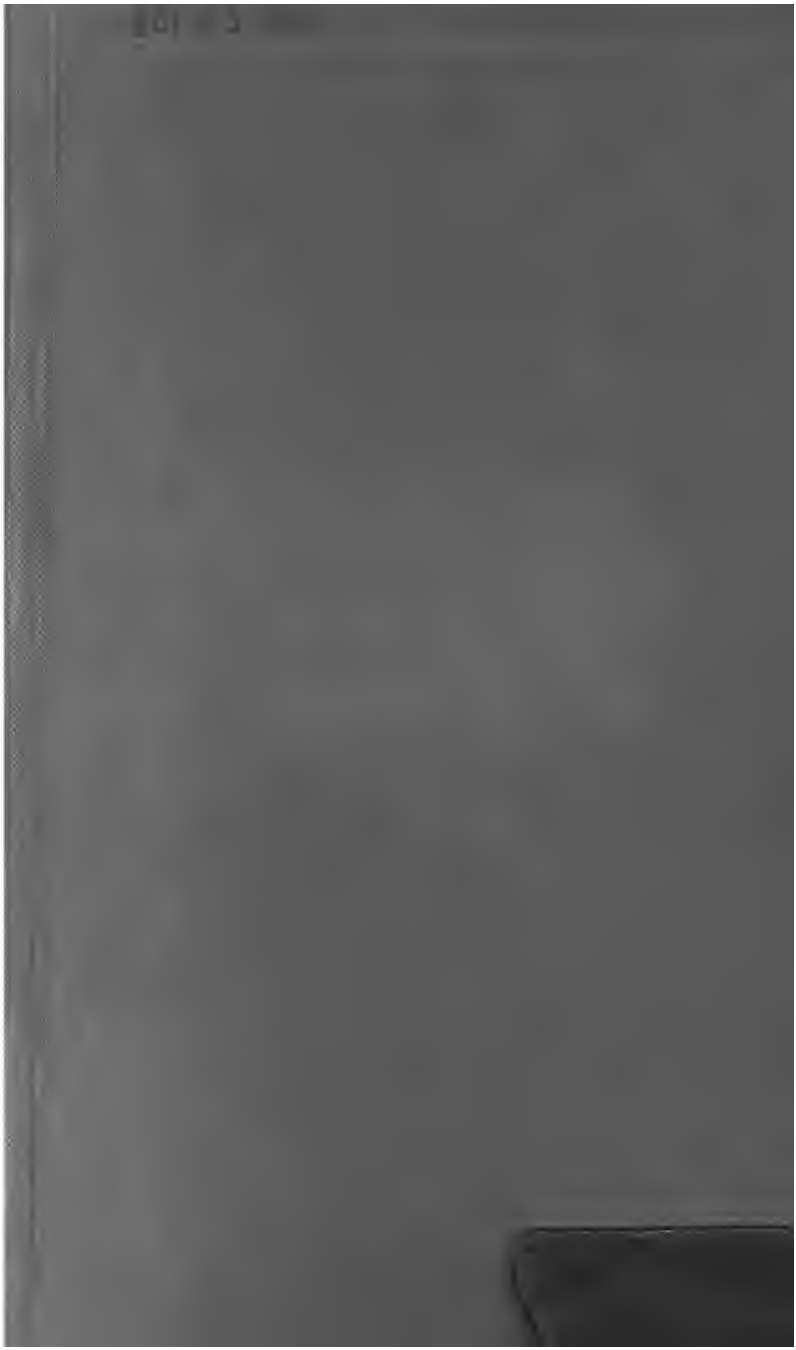
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